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ENGINEERING FIELD ACTIVITY WEST
NAVAL FACILITIES ENGINEERING COMMAND
HUNTERS POINT ANNEX
SAN FRANCISCO, CALIFORNIA

RESULTS OF SUBSURFACE RADIATION INVESTIGATION IN PARCELS B AND E

DRAFT FINAL REPORT
VOLUME I, MAIN REPORT, APPENDICES A, C, AND D

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PRC Environmental Management, Inc. (PRC) has conducted the second phase of a three-phase environmental radiation investigation at Hunters Point Annex (HPA), San Francisco, California. This investigation is under the Comprehensive Long-Term Environmental Action Navy (CLEAN) Contract N62474-88-D-5086, Contract Task Order (CTO) Number 0155, on behalf of the Department of the Navy, Engineering Field Activity West (EFA WEST), Naval Facilities Engineering Command.

The investigation for subsurface radium-containing materials was performed within Parcel E in the Industrial Landfill (IR-01), the Bay Fill Area (IR-02), and the Oily Waste Disposal Area (IR-14). Also, the investigation was performed in Parcel B in the Submarine Base Area (IR-07) and the Waste Oil Disposal Area (IR-18). Trenching, air permeability testing of soils, and downwell gamma logging were used during the investigation to identify the subsurface extent of these radium-containing materials. A total of 42 test pits and 3 trenches were excavated, 5 air permeability corings were collected, and 22 groundwater monitoring wells were logged for gamma activity.

The phase I surface radiation survey, conducted in 1992, identified over 300 near-surface point sources in IR-02 that contain radium-226 (^{226}Ra). Results of the phase II investigation completed in 1993 and provided in this report, indicated that approximately 111 discrete, subsurface gamma emitting point sources are buried in IR-02 to a maximum depth of 9 feet, in an area measuring approximately 400 feet long by 250 feet wide. The radium-containing point sources include illuminators, ship instruments, and dials with an approximate activity of one microcurie each.

The volume of soil in IR-02 that contains these individual point sources was calculated to be approximately 5,500 cubic yards. Based on trenching data, five point sources, with an average activity of one microcurie each, are in each 10 cubic yards of soil. These point sources represent an estimated aggregate ^{226}Ra activity of approximately 2.8 millicuries. No subsurface gamma-emitting point source materials were found within IR-01, IR-07, IR-14, and IR-18.

Test pits excavated in IR-07 and IR-18 revealed soils that exhibit gamma count rates approximately twice that of expected background. Preliminary results indicate that soils contain naturally occurring radioactive materials (NORM), including ^{226}Ra at levels slightly above expected background. Further investigation is needed to determine if these soils are imported or native fill.

1.0 INTRODUCTION

PRC Environmental Management, Inc. (PRC) has completed the second phase of a three-phase environmental radiation investigation at Hunters Point Annex (HPA), San Francisco, California. This investigation is under the Comprehensive Long-Term Environmental Action Navy (CLEAN) Contract N62474-88-D-5086, Contract Task Order (CTO) Number 0155, on behalf of the Department of the Navy, Engineering Field Activity West (EFA WEST), Naval Facilities Engineering Command.

1.1 OBJECTIVE OF SUBSURFACE RADIATION INVESTIGATIONS

One objective of this subsurface radiation investigation at HPA is to provide information about the distribution of radium-containing materials within two disposal landfills: the Industrial Landfill, Installation Restoration (IR) site-01 (IR-01), and the Bay Fill Area (IR-02). These two IR sites are located within Parcel E. In addition, phase II will also establish if naturally occurring radioactive materials (NORM) are the source of elevated gamma activity in soils at the Submarine Base Area (IR-07) and the Waste Oil Disposal Area (IR-18).

By determining the approximate surface and subsurface extent of the radioactive material and estimating the soil volumes, this report will assist the U.S. Environmental Protection Agency (EPA), the California Department of Health Services (DHS), and the Navy in identifying remedial alternatives to address the radium-containing materials in the IR-01 and IR-02 landfills. Health risks from radium-containing point sources and the application of remedial alternatives will be addressed in the Draft Parcel E Remedial Investigation report to be submitted at a later date.

Appendix A to this report presents the results of gamma spectroscopic analysis and air permeability testing. Appendix B contains trench logs, contour plots of the distribution of radioactive materials in the IR-02 landfill, and graphic representations of predominate soil units that surround the disposal area. Appendix B is Volume II of this two-volume report.

1.2 SUMMARY OF RADIATION INVESTIGATIONS AT HPA

Radiation investigations at HPA are being performed in three phases, as documented below.

1.2.1 Investigation Phases

Phase I was completed in 1992 and is known as the Surface Confirmation Radiation Survey (SCRS). The SCRS investigation (PRC 1992) was conducted in IR-01, IR-02, the Oil Reclamation Ponds (IR-03), IR-07, and IR-18. The SCRS was performed to detect elevated gamma activity due to radioactivity from radium-226 (^{226}Ra) and operations associated with the Naval Radiological Defense Laboratory (NRDL). The SCRS combined the systematic screening of landfill areas, using surface gamma radiation surveys, soil sample analysis, groundwater analysis, soil radon flux measurements, downwell gamma radiation logging, and cursory radiation surveys of selected buildings and sites (PRC 1992).

Phase II, the results of which are contained in this report, implemented SCRS recommendations to investigate subsurface conditions in the areas where elevated gamma activity was detected. These recommendations include the investigation of the extent and radiological content of gamma-emitting soils in IR-07 and IR-18, suspected to contain elevated amounts of NORM.

Phase III of the investigation, begun in the winter of 1994, is evaluating past activities associated with NRDL operations and formerly used defense (FUD) sites, complete the surface gamma survey of IR-02 that were inaccessible during the SCRS, and investigate the radiological content of tidal and intertidal zones not surveyed in previous investigations by the Navy (PRC 1992) and U.S. EPA (EPA 1989).

1.2.2 Phase I Radiation Investigation Results

When ^{226}Ra had been identified in IR-01 and IR-02 during phase I, high-volume air sampling was performed at HPA to establish the concentration of airborne radioactive particulates in air at and in areas around the sites. Sampling was conducted to determine if airborne alpha or beta activity exceeded health and safety limits. The air sample filters were analyzed for gross alpha and beta activity to establish background concentrations of long-lived radioactive airborne alpha- and beta-emitting particulates associated with ^{226}Ra. Sampling was conducted during activities that did not disturb the soil or cause resuspension of dust. Results indicated that concentrations of gross alpha- and beta-emitting airborne particulates at HPA were within the range of ambient or normally expected background levels (PRC 1992a).

The surface soils in IR-01, IR-02, IR-07, and IR-18 were surveyed for elevated gamma activity. Historical accounts of activities in IR-01 and IR-02 indicate that during routine maintenance operations on Navy ships and submarines, unserviceable radium-containing devices were removed and disposed of in the IR-01 and IR-02 landfills. These radium-containing devices were mainly instrument dials and illuminators. Although ^{226}Ra emits primarily alpha radiation, such devices can be located by their gamma-emitting decay progeny (daughters). In buried devices that have an activity of approximately one microcurie (μCi), the gamma radiation emitted by the daughters can usually be detected to a depth of approximately 1 foot.

The 1992 SCRS identified over 300 radium-containing devices, in surface soils, within an approximate 36,000 square foot (ft^2) area of the 2,177,000 ft^2 IR-02 landfill. This limited area comprises about 2 percent of the total area of the IR-02 landfill. Three devices were identified in surface soils of IR-01. Soils surveyed in IR-07 and IR-18 exhibited elevated gamma count rates; however, no point sources were identified. Surface soil samples that were collected in IR-18 contained concentrations of ^{226}Ra that are not above normally expected background levels. One soil sample within IR-07 contained 5.4 picocuries per gram (pCi/g) ^{226}Ra which is above expected background levels.

The results of the SCRS showed that ^{226}Ra-containing materials in surface soils are present in concentrations above normally expected background levels in IR-01, IR-02, and IR-07. Because there were no point sources identified in the field at IR-07, the U.S. EPA analyzed soil samples collected from this site and found that all activity in them is due to non-enhanced, naturally occurring radioactive materials (EPA 1994 and PRC 1995). The results of the SCRS also indicated that no mixed fission products are present in soils sampled at IR-01, IR-02, IR-03, IR-07, and IR-18. Finally, the results revealed that other than ^{226}Ra associated with radioluminescent dials and guages detected in IR-01 and IR-02, all radioisotopes in soil samples are within expected background levels at all sites.

1.3 BACKGROUND

Figure 1 shows the location of HPA within the San Francisco Bay Area. A brief general and radiological history of the facility follows.

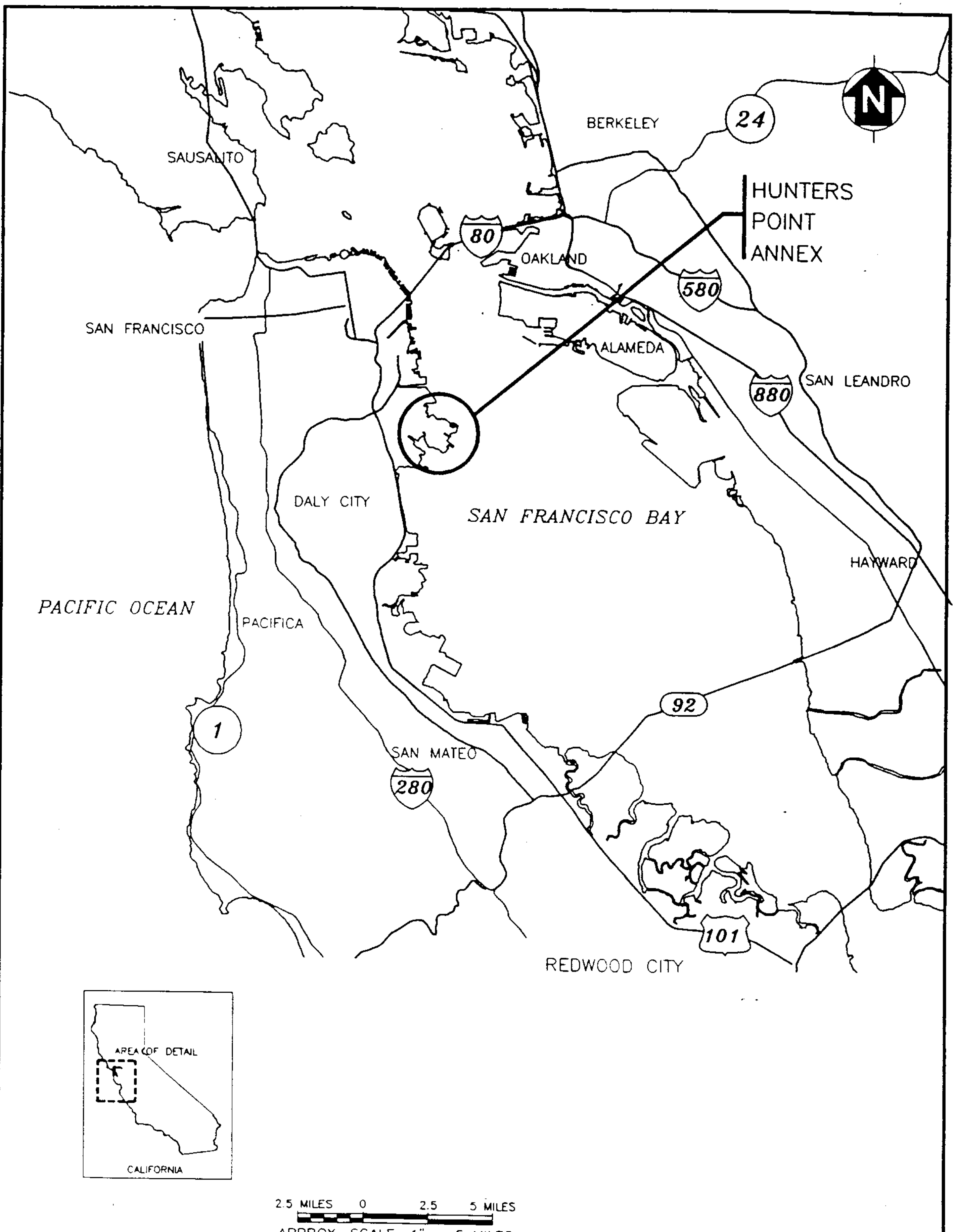


FIGURE 1
REGIONAL SETTING

WD(SF)(044-0155) HP-LOCDWG - 12/14/94 - PLOT 1=00 REV.0001

1.3.1 General History

The land that is now HPA was privately held until 1939 when the Navy purchased the property and leased it to Bethlehem Steel. At the start of World War II in 1941, the Navy took possession of the property from Bethlehem Steel and operated the shipyard until 1974. By then, except for minor facility maintenance, most official Navy activities at HPA had ended. In 1976, Triple A Machine Shops Incorporated (Triple A), a ship maintenance firm, leased the facility from the Navy. Triple A subleased many buildings at HPA to private commercial and light industrial firms (Harding Lawson Associates 1988).

HPA has been placed on the EPA's National Priorities List (NPL), and is currently undergoing site inspection (SI) and remedial investigation/feasibility study (RI/FS) activities. These SI and RI/FS activities include soil and groundwater sampling, air monitoring for chemical and radioactive contaminants, underground storage tank removal, and surface/subsurface radiation surveys of land areas and selected FUD and NRDL sites.

1.3.2 HPA Radiological History

HPA was a center of shipbuilding and ship repair during World War II. As was common until 1970, ^{226}Ra in the form of radium-sulfate was used extensively in shipboard radioluminescent markers, dials, clocks, and other instrumentation. The radium mixture produced a dull glow that made it easy to read instruments at night without additional lighting. Up until the late 1960s, it was common industrial practice to dispose of unserviceable radium-containing devices by shallow land burial. Results presented in this report indicate it is possible that over 2,700 of these devices may have been disposed of in a limited area within IR-02.

Pure and applied radiological research also played a major role in HPA's history. In 1948, a group of scientists at HPA formed the NRDL whose mission was to study the effects of nuclear weapons and to develop from them effective countermeasures against radiation. HPA was selected as the preferred West Coast site for NRDL due to its proximity to the University of California (U.C.) Crocker Radiation Laboratory, other Navy facilities, and its drydock capacity. NRDL activities required a cyclotron, a Van de Graaff generator, X-ray machines, radiological laboratories, support offices, and kennels for animals used in radiological studies.

In late 1946, a small group of personnel, comprising U.C. and navy scientists, was tasked with identifying methods to decontaminate ships that had returned from nuclear weapon tests near Bikini Atoll in the Marshall Islands known collectively as Operation Crossroads (Cook 1988).

Ships were returned to HPA drydocks after Operation Crossroads for decontamination studies after they were found to be resistant to radiological decontamination techniques that employed water blasting. Many methods of decontamination were tried before sandblasting was determined to be the only method that satisfactorily removed the contamination (Weisgall 1994). It has been postulated that fallout particles, including cesium-137 and plutonium-239, may have been mixed with sandblast wastes that were generated during Operation Crossroads decontamination activities. There is no documentation that supports the disposal of contaminated sandblast at HPA. Soil samples collected during the SCRS were analyzed for mixed fission products and plutonium. Mixed fission products and plutonium in soils were not detected in concentrations above normally expected background levels associated with worldwide atmospheric fallout (PRC 1992).

Navy documentation has established that all radioactive sandblast waste material and radioactive hull scrapings generated from decontamination were properly packaged and disposed of by ocean dumping. During 1946 and 1947, radioactive wastes from these activities were dumped in an approved zone near the Farallon Islands, 25 to 40 miles offshore from San Francisco (U.S. Navy 1949).

1.4 PARCEL-SPECIFIC RADIATION INVESTIGATIONS

Areas of HPA have been divided into parcels to facilitate transition of Navy property to the City of San Francisco. Parcel boundaries are based upon geographic location, site contamination, and proposed future land use. Two parcels, B and E, contain sites that have radiological concerns. Figure 2 shows each radiological IR site and the parcel in which it is located.

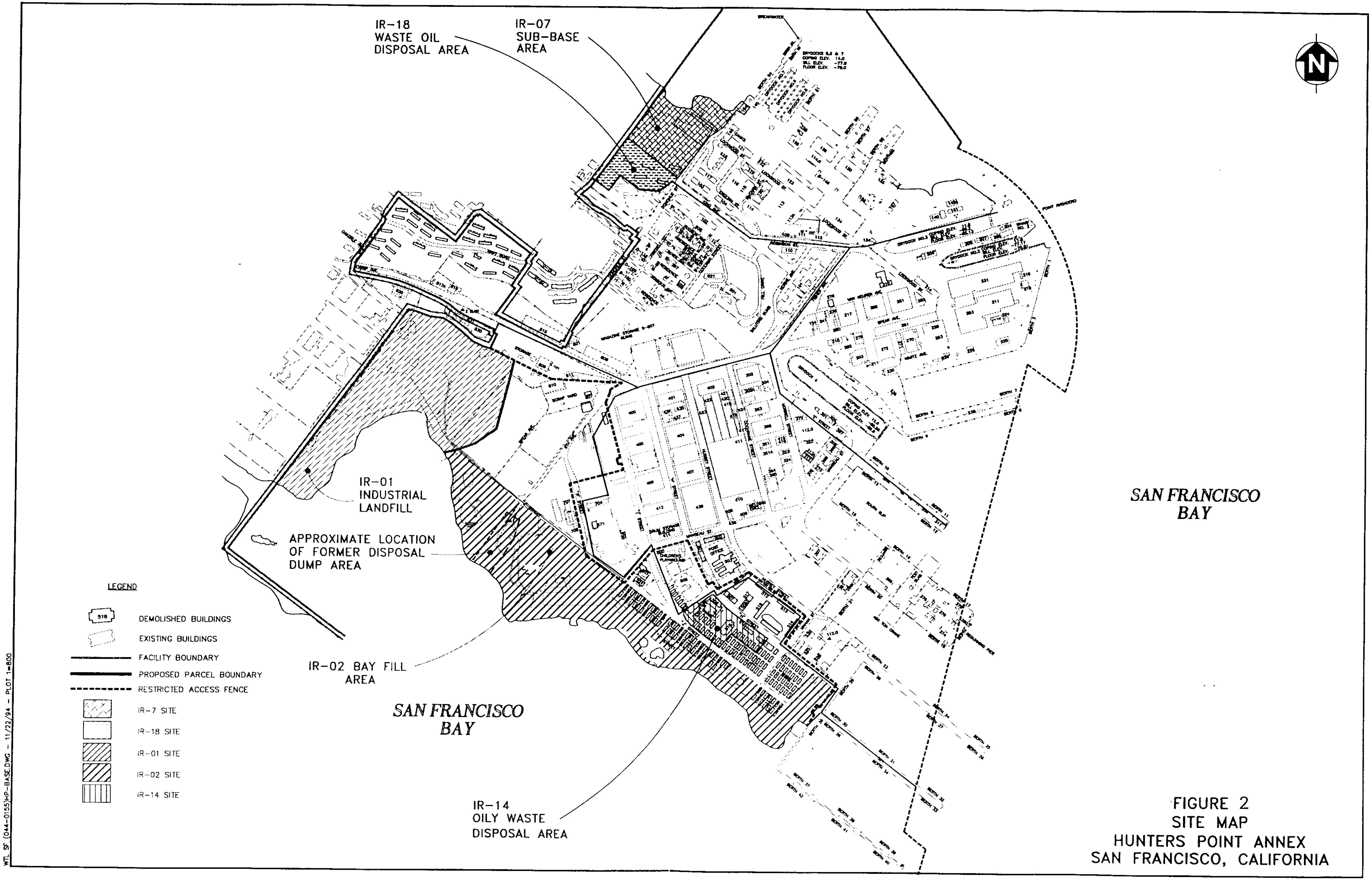


FIGURE 2
SITE MAP
HUNTERS POINT ANNEX
SAN FRANCISCO, CALIFORNIA

1.4.1 Parcel B

There are 12 IR sites within Parcel B. IR-07 and IR-18 were investigated during the SCRS and found to contain soils that emit elevated count rates due to gamma radiation. These soils are restricted to an area approximately 100 feet wide by 400 feet long on the hillside immediately northeast of building 916. The hillside is topped by Donahue Street. The level portions of IR-07 and IR-18 are adjacent to each other. They are approximately 25 feet below Donahue Street and are paved with asphaltic concrete. HPA lessees use these level areas for parking.

During the 1940s and 1950s, the Navy created the flatland area of IR-07 and IR-18 by filling in the northern bay margin during its activities at the shipyard. Many buildings that were constructed on this fill have since been demolished. IR-07 was originally used by the Navy in support of submarine maintenance, as an area for sandblast grit disposal, industrial landfill operations, and painting. IR-18 was designated as a Triple A contamination site. Waste oil spread over the soil surface was paved over with asphaltic concrete. IR-18 was last used by Triple A as a recreational vehicle campground and parking lot.

Although no point source gamma-emitting anomalies were identified in IR-07 and IR-18 during the SCRS, concern existed that elevated gamma count rates were possibly the result of radioactive contamination from the sandblast waste after Operation Crossroads. One soil sample collected during the SCRS was found to contain approximately 5.0 pCi/g ^{226}Ra. Since the normally expected background level of ^{226}Ra for soils in the San Francisco Bay Area is approximately 0.5 pCi/g, these findings prompted the inclusion of IR-07 and IR-18 in the phase II subsurface radiation investigation.

1.4.2 Parcel E

There are 24 IR sites within Parcel E. IR-01 and IR-02 were investigated during the SCRS and found to contain point sources of ^{226}Ra within 1 foot of the landfill surface. Only three point sources were found in IR-01. The area within IR-02 that contains these materials is approximately 250 feet wide by 400 feet long, centered 500 feet west of building 600 (local grid coordinate H.00.00 by 16.00.00). IR-01 and IR-02 have been used extensively as disposal sites for waste generated during HPA industrial activities. The Navy created this land area by filling in the bay margin during its activities at the shipyard. IR-01 and IR-02 were created largely by quarrying the Hunters Point peninsula which primarily consists of serpentinite bedrock. The bedrock was quarried then dumped into the bay. Many temporary buildings (Quonset Huts and plywood sheds) that were constructed on this fill have since been demolished, and the surface is now littered with debris.

Aerial photographs of the IR-01 and IR-02 landfill area, taken during the period from 1948 to 1958, indicate that the soils surrounding grid point H.00.00 by 16.00.00 may have been disturbed by periodic disposal activities. Site maps provided by the Navy show an area referenced as the "Disposal Dump Area." As shown on Figure 2, this former disposal area is west of building 600 at the south end of Sixth Avenue.

No useful aerial photographs of HPA exist that assist historical reconstruction of landfill placement activities. At the start of World War II, in the interest of national security, the Navy confiscated all aerial photographs and negatives held by local survey companies, for the years between 1938 and 1948. It is known that in the 1970s Triple A excavated a disposal trench in the area near grid coordinate H.00.00 by 16.00.00. This trench may have disturbed soils around the former Disposal Dump Area, uncovering radium-containing materials and bringing them to the surface of the landfill.

2.0 FIELD OPERATIONS

Phase II field operations were conducted from January 21, 1993, through July 25, 1993, in IR-01, IR-02, IR-07, IR-14, and IR-18. Operations included trenching, soil sampling, downwell gamma logging of selected groundwater monitoring wells, soil coring for air permeability testing, and air sampling. Only downwell gamma logging was conducted in IR-14. Before field activities began each day, a field meeting was held with the operations personnel that detailed the work to be performed that day and the safety issues related to that work.

2.1 LOCAL SURVEY GRID PLACEMENT AND COORDINATE DESCRIPTION

Figure 3 is a local survey grid used during phase II trenching activities to reference test pit and trench locations. The local grid pattern was established during phase I of the radiation investigation. Grids 300 feet by 300 feet were surveyed over IR-01, IR-02, IR-03, IR-07, IR-14, IR-15, and IR-18. At

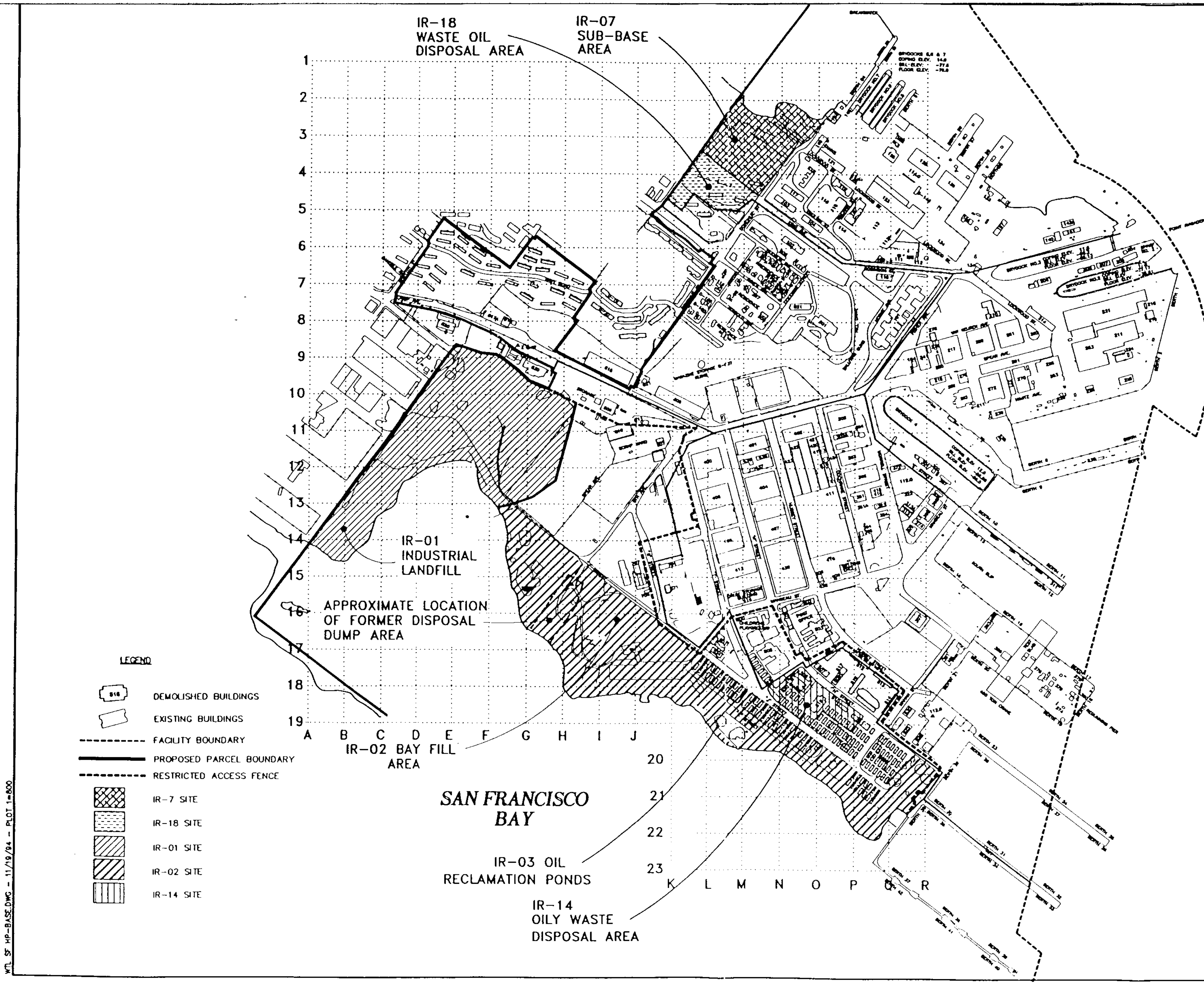


FIGURE 3
LOCAL GRID COORDINATE
PLACEMENT AND LOCATION OF
IR SITES INVESTIGATED
HUNTERS POINT ANNEX

each 300-foot grid node, a semipermanent monument consisting of a 6-foot steel fence post and a spike were driven into the ground. Approximately 76 monuments were installed. The grid was oriented along true north and correlated to the California Coordinate System as shown. The grid was further subdivided on 60-foot centers. Twelve-inch steel spikes, marked with plastic surveyor's tape, were driven at 60-foot intervals to create 25 points per 300-foot grid sector space. Each major 300-foot grid axis was given a label. East-west-running axes (X axis) were labelled with the letters A through R. North-south-running axes (Y axis) were labelled with the numerals 0 through 23. Each X and Y axis between 300-foot grid nodes was further subdivided into ten 30-foot divisions. These divisions were labelled 1 through 9 from west to east on the X axis and 1 through 9 from north to south on the Y axis.

Divisions between 30-foot nodes were measured in feet. For example, the grid coordinates H.03.24, 17.08.12 represent the following: X-coordinate H, plus three 30-foot grid blocks east plus 24 more feet east, intersected by, Y-coordinate 17, plus eight 30-foot grid blocks south plus 12 more feet south.

2.2 TEST PITS AND TRENCHES

Test pit and trench locations were selected based upon SCRS results that identified elevated gamma count rates in surface soils. To define the subsurface extent of radioactive materials, excavations were made in and surrounding these areas. (Refer to Figures 4 through 7.)

Test pits and trenches are identified on figures and geologic logs as TP and TR respectively. All excavations were made along a north-south axis using a backhoe with a 2-foot-wide bucket. Each test pit was approximately 15 feet long by 2 feet wide by 8 feet deep. Each trench was approximately 100 feet long by 2 feet wide by 8 feet deep. The location of both ends of each excavation site was marked with wooden stakes before field work started. Health physics personnel surveyed the ground surface before excavation began, using a gamma ray detector coupled to a ratemeter/scaler. (Refer to Section 2.8 for instrumentation used.) A pressurized ionization chamber was used to measure the gamma exposure rate at each excavation site at 3.0 feet above the ground surface. During excavation, health physics personnel surveyed all test pits and trenches for radiation and a field geologist logged soil type and the location of gamma anomalies. Excavations proceeded as follows: (1) 1 foot of soil

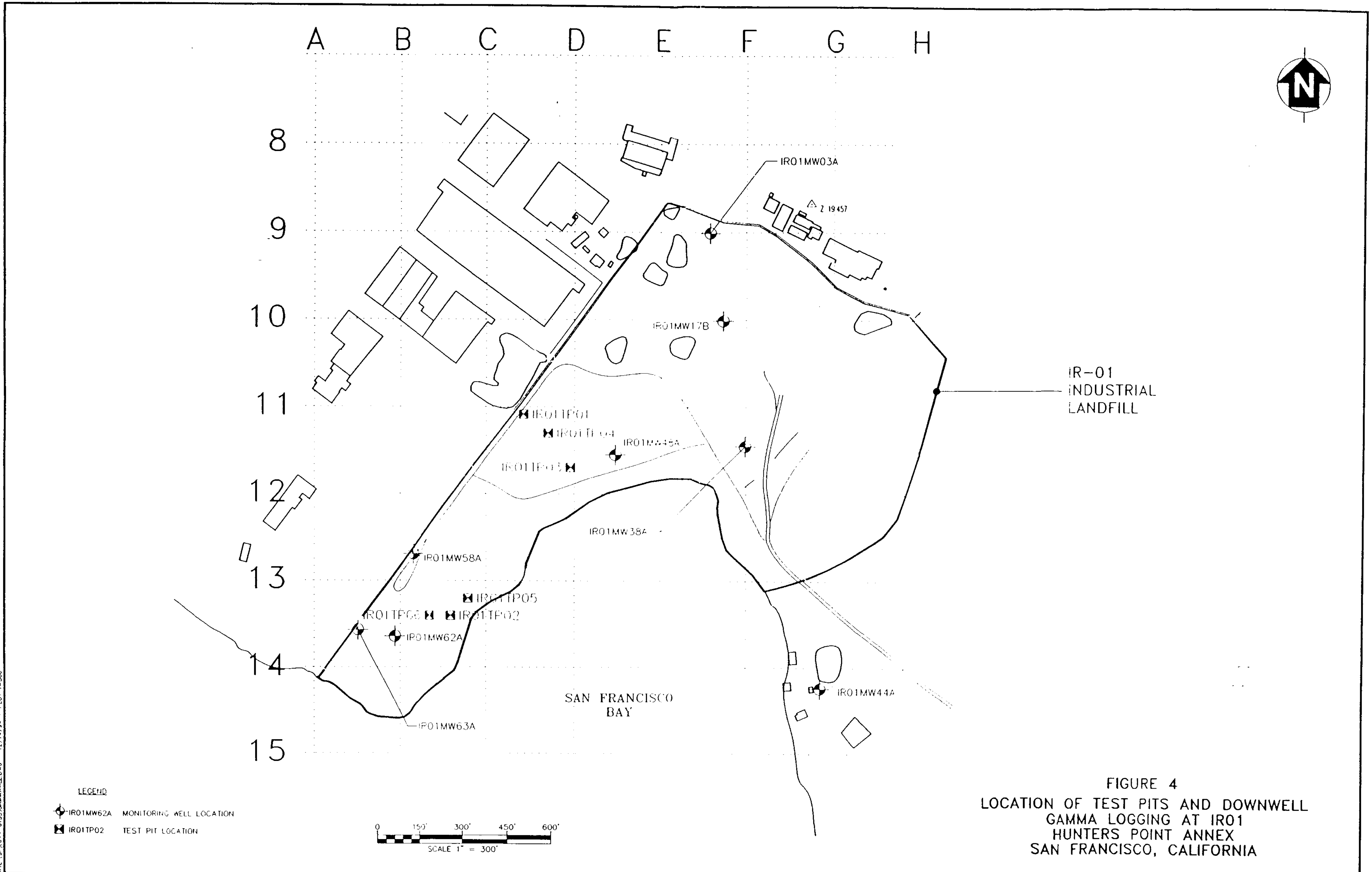


FIGURE 4
LOCATION OF TEST PITS AND DOWNWELL
GAMMA LOGGING AT IR01
HUNTERS POINT ANNEX
SAN FRANCISCO, CALIFORNIA

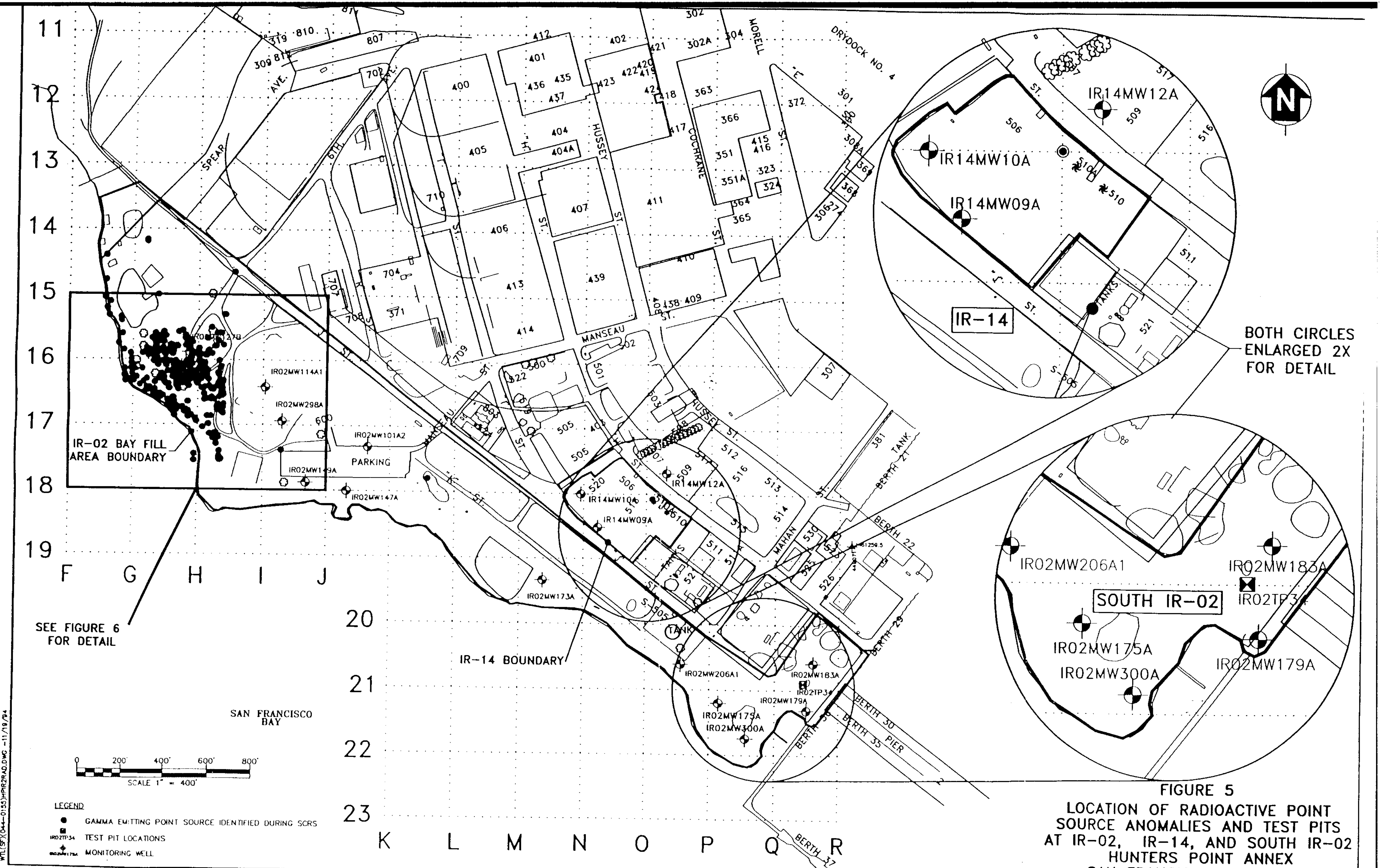


FIGURE 5
LOCATION OF RADIOACTIVE POINT SOURCE ANOMALIES AND TEST PITS AT IR-02, IR-14, AND SOUTH IR-02
HUNTERS POINT ANNEX
SAN FRANCISCO, CALIFORNIA

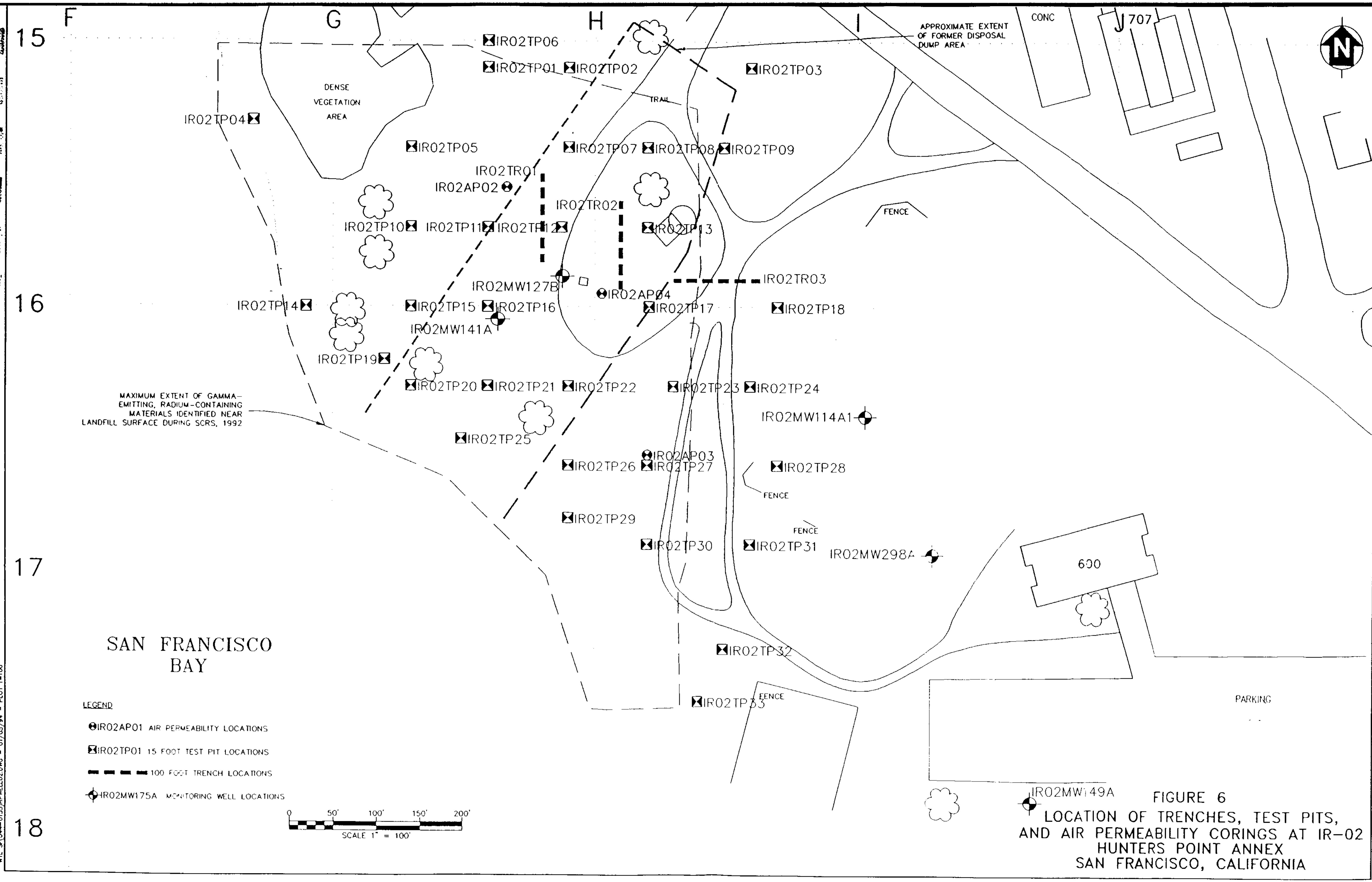
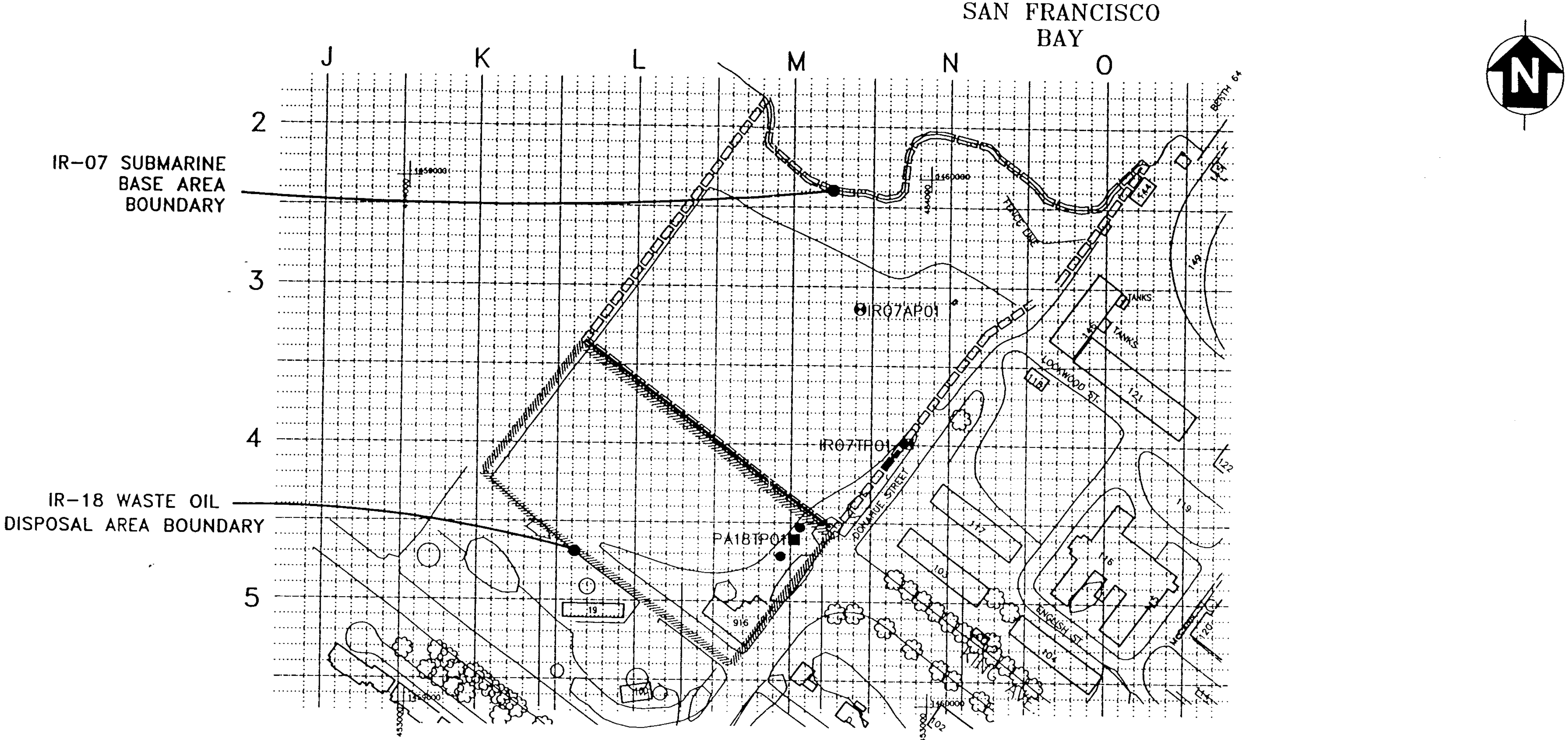


FIGURE 6
LOCATION OF TRENCHES, TEST PITS, AND AIR PERMEABILITY CORINGS AT IR-02
HUNTERS POINT ANNEX
SAN FRANCISCO, CALIFORNIA



LEGEND

IR07AP01	AIR PERMEABILITY CORING LOCATION
IR18TP01	TRENCH LOCATION
	IR07 BOUNDARY
	IR18 BOUNDARY
●	LOCATION EXHIBITING ELEVATED GAMMA COUNT RATE IDENTIFIED DURING 1992 SCRS
916	BUILDING 916

0 100' 200' 300' 400'
SCALE 1" = 200'

FIGURE 7
LOCATION OF TEST PITS, AIR PERMEABILITY CORINGS, AND RADIOACTIVE ANOMALIES AT IR-07 AND IR-18
HUNTERS POINT ANNEX
SAN FRANCISCO, CALIFORNIA

cover was excavated with the backhoe bucket, (2) excavated soil was deposited in a spoils pile adjacent to the excavation, (3) the walls and bottom of the excavations were surveyed by health physics personnel for gamma activity, and (4) the spoils pile was surveyed for gamma activity. If elevated gamma count rates were detected in the excavation or spoils pile, the source was identified if possible, removed, and its location and gamma count rate intensity recorded. A geologist logged each trench and recorded the stratigraphy of the soils, types of materials found in the trenches and test pits, and the approximate locations of all detected gamma anomalies. Radioactive material that was removed was drummed, or sampled and sent to a laboratory for analysis. This excavation process was continued until backhoe refusal occurred, trench walls became unstable, or groundwater or bay mud was encountered. Excavation continued below 8 feet if groundwater or in-place native soils (bay mud) were not encountered. Each excavation was backfilled with its own spoils after gamma and geologic logging were completed, and any radioactive sources were removed from the soil.

Soils and debris that contained no identifiable radioluminescent devices (dials, gauges, illuminators, or buttons) that clearly were the source of elevated gamma activity, were sampled and sent to a laboratory for further analysis. Radioactive material that clearly was a radioluminescent device was not sent to a laboratory and was placed in the low-level radioactive storage area in building 130.

2.2.1 Trench Log Description

Each trench log includes the site-specific soil stratigraphy, the number and location of gamma anomalies, the general gamma count rate at depth, and the date soil samples were collected and their identification (ID) numbers.

2.2.2 Soil and Material Classification

A modified Unified Soils Classification System (USCS) was used to characterize the soil in each excavation. (The USCS was modified because HPA fill material does not clearly follow specific USCS guidelines.) Color, grain size, water content, consistency, and relevant secondary characteristics or features were identified. The characterization involved identifying the predominant soil types: clay (C), silt (M), sand (S), and gravel (G). Besides these four basic soil types, two other units occurred frequently enough in excavations to be classified separately: serpentinite fill (SF) and debris (D).

Serpentinite fill consists of serpentinite gravel, cobbles, and boulders in a clay-rich matrix. Industrial waste debris consists of any of the other lithologic units that contained more than 50 percent concrete, brick, wood, metal, glass, plastic, or other waste material. Summary descriptions of each distinct soil type encountered in excavations are presented on trench logs in Appendix B, which is in Volume II.

2.2.3 Stratigraphy, Materials, and Gamma Anomalies

Each trench log covers the site-specific soil stratigraphy and provides the most detailed sketch possible of debris or other special features that may relate to gamma-emitting anomalies.

2.3 EXCAVATIONS IN IR-01, IR-02, IR-07, AND IR-18

Trenching was used as a method to identify the subsurface extent of radioactive materials in landfill areas. Six test pits were excavated in IR-01 as shown on Figure 4. Thirty-four test pits and three trenches were excavated in IR-02 as shown on Figures 5 and 6. One test pit was excavated in IR-07 and one was excavated in IR-18 as shown on Figure 7.

2.3.1 Radioluminescent Devices

Gamma-emitting point sources in IR-02, clearly identified as radioluminescent devices, were not collected for analysis. These materials were removed from the soil, placed in properly labeled drums, and stored in the low-level radioactive waste structure within building 130. Soil that exhibited diffuse gamma activity, associated with radioluminescent devices, was sampled and sent to a laboratory for gamma spectroscopic analysis.

2.3.2 Background Gamma Count Rates in Excavations

Subsurface soils in landfill disposal areas contain a number of materials, some of which are naturally radioactive, such as fire brick, clays, and granite curbs. Thus, using the sodium iodide (NaI) instrument described in section 2.8, the background gamma count rate in excavations varied from approximately 5,000 to 10,000 counts per minute (cpm), depending on depth and debris content. If a count rate at a specific location in an excavation exceeded the background count rate by approximately one and one-half times, this area in the excavation was investigated for the source of gamma activity.

The following method was used to determine the background gamma count rate in excavations. First, the entire trench was gamma logged at a specific depth. The general background gamma count rate range was recorded. Excavations had a background gamma count rate ranging from 5,000 to 10,000 cpm. At these rates, a health physics technician, using an audio speaker to listen to count rates, can usually detect a change when the rate increases or decreases approximately 50 percent. Therefore, if any count rates in any area of an excavation exceeded the established background count rate by one and one-half times, the area was mapped on a trench log and was investigated for a source of the gamma activity.

2.4 DOWNWELL GAMMA LOGGING

Downwell gamma logging was used to survey 22 existing groundwater monitoring wells within IR-01, IR-02, IR-07, IR-14, and IR-18, to identify subsurface areas of elevated gamma activity. Eight wells were logged in IR-01, 12 in IR-02, and 2 in IR-14. Wells were not logged in IR-07 and IR-18. Elevated gamma activity encountered during gamma logging is used as an indicator of buried gamma-emitting material within 1 to 2 feet of a well casing.

The downwell gamma logging survey employed the same gamma ray detector that was used for gamma logging test pits and trenches. (Refer to Section 2.8 for instrumentation used.) Shielding allows detection of gamma rays at discrete depths. The detector was lowered into each well to a maximum depth of 20 feet, or to the bottom of the well, whichever was less. The detector was then raised in 1-foot increments, held at each level for 30 seconds, while an integrated gross gamma count rate measurement was recorded. Thirty-second-long integrated measurements were taken at 1-foot increments until the detector was even with the ground surface.

The phase II radiation investigation final field work plan (PRC 1993) listed specific wells to be gamma logged. Several monitoring wells could not be located by field personnel or could not be used for gamma logging because the well casing was less than 2 inches in diameter. Based on accessibility and location, additional wells were selected for downwell gamma logging during field operations. Figures 4, 5, and 6 show the locations of monitoring wells that were downwell gamma logged. The method used to compare gamma count rates to well-specific background was the same as detailed in Section 2.3.2. Copies of the pages from the field log book are provided in Appendix C of this report.

2.5 SOIL CORING FOR AIR PERMEABILITY TESTING

Air permeability testing of soil was to be performed at a total of 10 locations within IR-01, IR-02, and IR-07. Large amounts of subsurface metal and wood debris were present at sampling locations, which caused many refusals. Therefore, it was only possible to collect five soil cores for air permeability testing. If a refusal was encountered, the coring location was moved 2 feet away from the original location and another attempt at one sampling was made. After three refusals around the coring location, the site was abandoned.

A continuous soil sample core was collected at each location. Soils from the surface to approximately 2 feet below ground surface (bgs) were collected using 3-inch-diameter by 36-inch-long stainless steel Shelby tubes. Each tube was pushed into the ground, without using a rotary motion, by the weight of the drill rig. A new Shelby tube was used at each location. Soil cores were sent to an off-site laboratory where American Petroleum Institute (API) Method RP 40 was used to evaluate the soil's air permeability.

A total of five soil corings were collected for air permeability analysis within IR-02 and IR-07. Figures 6 and 7 show the air permeability coring locations. Four samples were collected in IR-02 and 1 was collected in IR-07. Samples were not collected from IR-01 because deep mud and rainwater from recent precipitation covered the site. Air permeability data for landfill soils was to be used to assist in the evaluation of the radon gas flux rate measurements obtained during the SCRS. Radon releases result from the radioactive decay of ^{226}Ra. During the SCRS, sampling containers, filled with activated carbon, were set out to measure the radon-222 (^{222}Rn) flux rate at the soil-air interface.

2.6 AIR SAMPLING FOR GROSS ALPHA- AND BETA-EMITTING PARTICULATES

Air sampling for gross alpha- and beta-emitting particulates was performed during soil excavation. Airborne particulate sampling was done to assess whether radioactive dusts were being resuspended from the soil into the air during excavation activities. Gross alpha- and beta-emitting airborne particulates were monitored throughout each day in three locations: (1) the breathing zone of workers at the excavation site, (2) immediately downwind from the excavation site, and (3) at the upwind and downwind portions of the perimeter of the excavation area (Zenitech 1993).

Low-volume air sampling pumps (approximately 2 liters per minute [lpm]) in series with particulate collection filters were used to monitor the breathing zone of workers at the excavation site. Medium-volume air sampling pumps (approximately 20 lpm) in series with particulate collection filters were used to monitor the air immediately downwind from excavation activities. Medium-volume samplers were placed approximately 15 to 20 feet from each trench or test pit. Low- and medium-volume air samplers collected particulates on cellulose ester filters with a 0.8 micron (μm) pore size.

High-volume air sampling pumps (approximately 1,400 lpm) were placed at a minimum of 60 feet and a maximum of 320 feet from trenches and test pits. High-volume air samplers collected particulates on 8-inch by 10-inch glass fiber filters with a 0.8 μm pore size.

2.7 EQUIPMENT AND PERSONNEL DECONTAMINATION

After each excavation was backfilled, the equipment and field personnel were frisked for radioactive contamination with a Ludlum Instruments 44-3 alpha scintillation detector and the Ludlum Instruments 44-9 Geiger-Mueller (GM) detector, to ensure that radioactive material was not removed from the controlled excavation area. (Refer to Section 2.8.) If radioactivity above background was detected on excavation equipment, a brush was used to remove gross amounts of soil. The equipment surface was then sprayed from a bottle filled with Radiacwash® (a citric acid based cleaner) and then wiped clean with a paper towel moistened with distilled water. Following decontamination, the dried equipment was resurveyed for residual surface contamination. If no residual radioactivity was found on it, the equipment was moved to the decontamination pad and steam cleaned to remove other potential chemical contaminants. If radioactive contamination was detected on field personnel protective equipment (PPE), it was removed and stored as dry radioactive waste. If further decontamination of PPE was needed, equipment decontamination methods were used to reduce surface activity to background levels.

All radiologically contaminated PPE and investigation-derived wastewater were placed in separate 55-gallon drums. All drummed radioactive waste material was labeled and placed in the low-level radioactive waste storage structure located within building 414 to await disposal by the Navy.

2.8 RADIATION DETECTION INSTRUMENTATION

All field radiation detection instruments were operationally field checked by a health physics technician before surveys began each day. Alpha detectors were operationally checked daily with a thorium-230. alpha source; beta/gamma and gamma detectors were checked using a cesium-137, beta/gamma source. If the count rate of any detection system exhibited variability that exceeded three standard deviations of the expected mean count rate, the equipment was repaired, recalibrated, or not used.

Test pits and trenches were gamma logged using a modified, lead-shielded, waterproof Eberline SPA-3 gamma scintillation detector, which has a 2-inch by 2-inch NaI crystal. The detector was coupled to a Ludlum Instruments Model 2221 ratemeter/scaler. The detector is approximately 8 percent efficient for gamma, using cesium-137. The cylindrically shaped detector has the NaI crystal shielded with lead sheeting so that incident gamma rays will be collimated. This collimation allows normal detection of gamma energies at right angles to the sides of the detector, while reducing sensitivity to gamma rays from above or below. When this detector is used, measurements of gamma activity at discrete depths is possible, and gamma count rate measurements are representative of specific soil planes. This instrument provides results in cpm.

The Ludlum Instruments Model 44-3 alpha scintillation detector, used as described in Section 2.7, has a 50-square-centimeter window, with an efficiency of approximately 19 percent for alpha using thorium-230 (^{230}Th). During contamination surveys, the detector was used with the analyzer in a 1-minute scaler mode. This instrument provides results in cpm.

The Ludlum Instruments Model 44-9 GM detector, used as described in Section 2.7, is approximately 30 percent efficient for ^{230}Th alpha emissions and approximately 60 percent efficient for strontium-90 beta emissions. This instrument provides results in cpm.

Gamma exposure rate measurements were taken with a Victoreen 450P pressurized ionization chamber. This instrument provides results in microroentgen per hour (μR/hr).

3.0 RESULTS OF FIELD INVESTIGATIONS

The following sections and subsections provide the results of trenching, downwell gamma logging, air permeability testing, and gamma spectroscopic analysis of soil samples. Table 1 lists the test pits and trenches where gamma-emitting materials were detected, and lists approximate number of anomalous areas identified. Table 2 lists the approximate number of radioactive point sources identified as a function of their depth in the landfill. The term "excavations" in this report indicates both test pits and trenches.

3.1 TEST PITS AND TRENCHES

The following sections describe the trench logging system and provide the findings of trenching within IR-01, IR-02, IR-07, and IR-18. Trenches in IR-01 did not exhibit elevated gamma count rates. Test pits and trenches excavated in IR-02 contained point source gamma-emitting anomalies. Trenches in IR-07 and IR-18 contained areas of generally elevated diffuse gamma activity; no point source gamma-emitting anomalies were found.

A trench log was prepared for each trench and test pit. Trench logs, located in Volume II, Appendix B, graphically display the distribution of soil types, debris, radioactive materials, and their associated gamma count rates at specific depths in each excavation. The logs also depict the location and placement of gamma count rate anomalies within each excavation.

Gamma exposure rate measurements collected (450P Victoreen) at the surface at all locations within the four IR sites were consistent with expected background levels. The exposure measurements observed between 7-12 microroentgen per hour (μR/hr) at 1 meter above the ground surface.

TABLE 1

ANOMALOUS GAMMA COUNT RATE RANGES AND NUMBER OF DISCRETE ELEVATED AREAS WITHIN EXCAVATIONS AT IR-02

Trench or Test Pit Number	Number of Gamma Count Rate Anomalies	Gamma Count Rate Ranges (CPM)	Comments
TR01	29	10,000 - 860,000	At 6.5 ft. bgs, exhibited elevated gamma count rate Trench Log No. IR02/TR01 [a]
TR02	35	10,200 - 1,000,000+	Trench Log No. IR02/TR02
TP07	1	10,000 - 54,000	Trench Log No. IR02/TP07
TP10	2	77,488 - 276,000	Trench Log No. IR02/TP10
TP12	6	15,000 - 116,000	Trench Log No. IR02/TP12
TP13	4	14,000 - 988,000	Trench Log No. IR02/TP13
TP15	3	11,000 - 43,000	Trench Log No. IR02/TP15
TP17	2	6,500 - 16,500	Trench Log No. IR02/TP17
TP20	2	10,000 - 11,000	Trench Log No. IR02/TP20 [a]
TP21	2	10,000 - 11,000	Trench Log No. IR02/TP21 [a]
TP22	4	9,100 - 215,000	Trench Log No. IR02/TP22
TP23	5	11,000 - 126,000	Elevated gamma count rate throughout trench and spoils. Trench Log No. IR02/TP23 [a]
TP25	4	11,000 - 405,000	Elevated gamma count rate throughout trench. Trench Log No. IR02/TP25 [a]
TP27	12	11,000 - 1,000,000+	Trench Log No. IR02/TP27

[a] Detailed explanation of comment provided in Section 3.1.2

TABLE 2

GAMMA-EMITTING ANOMALY LOCATION BY DEPTH IN IR-02

Depth (Feet bgs)	Number of Anomalies at Each Depth	Percentage of Total Number of Anomalies by Increasing Depth	Percentage of Total Number of Anomalies at Each Depth
Surface	3	2.7	2.7
0.5	0	2.7	0
1.0	15	16.2	13.5
1.5	11	26.1	9.9
2.0	0	26.1	0
2.5	10	35.1	9.0
3.0	9	43.2	8.1
3.5	0	43.2	0
4.0	8	50.4	7.2
4.5	4	54.0	3.6
5.0	11	64.0	9.9
5.5	6	69.4	5.4
6.0	10	78.4	9.0
6.5	9	86.5	8.1
7.0	3	89.2	2.7
7.5	4	92.8	3.6
8.0	6	98.2	5.4
8.5	1	99.1	0.9
9.0	0	99.1	0
9.5	0	99.1	0
10.0	1	100.0	0.9

3.1.1 IR-01

Six test pits were excavated within IR-01. No elevated gamma count rates were detected in any of the test pits. IR-01 is composed of a wide variety of soils and debris. The surficial soil is predominantly sand, ranging in thickness from 1 to 6 feet bgs. Typically below the surficial sand, heterogeneous industrial debris consisting of wood beams, concrete, sheet metal, rubber hoses, plastic, and brick form more than 50 percent and up to 75 percent of the ground mass. In some regions, serpentinite fill predominates over industrial debris. The depth to groundwater varied from 1 to 7 feet bgs and appeared to coincide with the San Francisco Bay sea level fluctuations and local rainfall events.

3.1.2 IR-02

Thirty-four test pits and three trenches were excavated within IR-02. Twelve test pits and two trenches were found to contain a total of 111 gamma-emitting point source anomalies. A total of 96 point sources, or approximately 90 percent, of the radium-containing devices were found between the surface and 6.5 feet bgs. Table 2 lists the number of elevated areas identified and the percentage of the total number of anomalies by depth.

Figure 6 shows test pits and trench locations where radium-containing materials were found within an area that surrounds grid coordinate H.00.00, 16.00.00. Gamma-emitting materials were identified in this area at the landfill surface during the SCRS.

All of the soil samples collected from trenches and test pits within IR-02 contained ^{226}Ra and its associated daughters. All samples that were collected were sent to a radiological laboratory for gamma spectroscopic analysis. Appendix A provides the laboratory analytical results for each soil sample. The laboratory identified only three radionuclides in the soil samples: ^{226}Ra, lead-214 (^{214}Pb), and bismuth-214 (^{214}Bi). ^{214}Pb and ^{214}Bi are decay daughters of ^{226}Ra.

Four excavations within IR-02 exhibited a gamma count rate distribution that differed from the rest of the excavations. IR02TR01 exhibited a general gamma count rate range of approximately 16,000 to 18,000 cpm at 6.5 feet bgs. This appeared to be due to the presence of crushed fire brick disposed of in a layer at this depth. IR02TP22 and IR02TP25 exhibited elevated gamma count rates in the test pit and spoils. Again, the presence of a large amount of firebrick caused a general elevation of 16,000 to 18,000 cpm in the gamma count rate. Additionally, in these two test pits a few crushed or decomposed radium-containing devices were found to have contaminated a small volume (1,000 cubic centimeters) of soil around them. In these cases, the activity was removed from the spoils pile by scooping the soil up with a shovel and placing it into a storage drum.

3.1.3 IR-07 and IR-18

One trench pit each was excavated in IR-07 and IR-18. The two test pits had an approximate 1-foot-thick layer of silty sand at the surface, which overlaid silts or sandy clays. Sandstone bedrock was encountered at 2.5 feet bgs in IR-07. Claystone bedrock was encountered at 2 feet bgs in IR-18. Point sources of elevated gamma activity were not detected in the test pits. Trench logs that document geologic descriptions and gamma count rate ranges within excavations are included in Appendix B, which is in Volume II of this report.

3.2 DOWNWELL GAMMA LOGGING

Of the 22 groundwater monitoring wells surveyed using a gamma detector, only 1 well had an elevated gamma count rate. A gamma count rate of 16,326 cpm was recorded in monitoring well IR02MW175A at a depth of 6.5 ft bgs. The remaining wells had gamma count rates indicative of background, ranging from approximately 6,800 to 10,200 cpm.

3.3 SOIL CORING FOR AIR PERMEABILITY TESTING

Soil cores collected for air permeability analysis did not render data that augmented results from radon flux rate measurements. Five of 10 proposed sampling locations provided a representative soil core, since the Shelby tube did not penetrate serpentine bedrock or industrial debris at those locations. Of those samples, only IR02AP03, IR02AP05, and IR07AP01 were suitable for analysis.

Results were provided in the standard permeability unit of millidarcy. A millidarcy is equivalent to one thousandth of a darcy, which is equivalent to the passage of 1 cubic centimeter of fluid of 1 centipoise viscosity flowing in 1 second under a pressure differential of 1 atmosphere through a porous medium having an area of cross section of 1 centimeter and a length of 1 centimeter.

Permeability results for samples were 15.6, 432, and 0.37 millidarcy. Air conductivity for the same samples was measured to be 1×10^{-6}, 2.8×10^{-5}, and 2.4×10^{-8} centimeters per second. These highly different results are typical for heterogeneous soil matrices. The soil types found in landfills at HPA, as described in section 2.2.2, are composed of four soil types: clay (C), silt (M), sand (S), and gravel (G). Besides these four basic soil types, two other units occurred frequently enough in the landfill to be classified separately: serpentinite fill (SF) and debris (D). Generally, the order of permeability for the four basic soil types (from lowest to highest) are C, M, S, and G. Usually, the two other soil units, SF and D, can be more permeable than G. Air permeability results are consistent with samples composed of various soil types and fall within expected values (Freeze 1979) provided on Table 3.

Air permeability results were to have been used to make qualitative inferences about the location of buried radium-containing material. For example, it was hypothesized if the soil at a specific location had high air permeability and had low or background radon flux rates, it would be unlikely that radium-containing materials were buried there. Because of soil heterogeneity at each of the sampling sites, a wide range of air permeability values were obtained. These results show that air permeability, when used independently, cannot be used as a good predictor of radon flux rates. Therfore, air permeability results will not be used to interpret radon flux rate measurements made during the SCRS. Appendix A provides the laboratory report for the analysis.

3.4 GROSS ALPHA AND BETA AIRBORNE PARTICULATE MONITORING

Levels of gross airborne alpha and beta particulate activity were found to be less than 10 percent of 10 CFR 20 standards. The report that documents airborne gross alpha and beta particulate activity in IR-01, IR-02, IR-07, and IR-18 during excavation is available upon request (Zenitech 1993).

TABLE 3
EXPECTED RANGE OF PERMEABILITY VALUES BY SOIL TYPE

Soil Type	Range of Permeability Values (millidarcy)
Clay	$1x10^{-5}$ - $1x10^{-1}$
Silt	$1x10^{-1}$ - $1x10^{3}$
Sand	$1x10$ - $1x10^{6}$
Gravel	$1x10^{5}$ - $1x10^{8}$

4.0 DISCUSSION OF RESULTS

This section discusses the results of trench excavation, air permeability testing, downwell gamma logging, and air sampling. Appendix B, which is in Volume II of this report, contains trench logs of excavations and figures that detail contamination depth and landfill lithology.

Figure B-1 in Appendix B is a map that shows the location of surface radioactive point sources that were identified during the SCRS. Figure B-1 has two clear plastic overlays. Overlay A is a contour plot of the maximum depth at which radioactive materials were found within the area that surrounds grid location H.00.00 by 16.00.00. Overlay B shows the location of test pits and trenches that were excavated in the same area.

Figure B-2 in Appendix B is a slice diagram of the distribution of predominant soil units, at 1-foot depth intervals, within the area that surrounds grid coordinate H.00.00 by 16.00.00.

4.1 TEST PIT AND TRENCH EXCAVATION

Excavation of soils at HPA was performed to establish (1) the subsurface extent of radioactive materials, (2) their character and identity, (3) soil stratigraphy, and (4) the identity of buried debris associated with radioactive anomalies. This data was collected by excavating test pits and trenches in and around locations that contain surficial anomalies.

4.1.1 IR-01

No subsurface gamma anomalies were detected in IR-01. IR-01 is composed of a wide variety of materials. The surficial soil is predominantly sand, ranging in thickness from 1 to 6 feet. In the southernmost test pit (TP02), however, this sand is covered with a thin veneer of sandy clay. Trench TP-02 also cuts through a remarkable body of slag that appears to be 100 feet wide and 400 feet long. This rust-colored slag contains melted bottles, large amounts of rusted steel and iron, and other scrap. As seen on Trench Log No. IR01/TP02, the slag is approximately 2 feet thick, but it was measured up to 3 feet thick locally. The origin of the slag is unknown.

Below the surficial sand, heterogeneous industrial waste debris (metal pieces, glass, large wood timbers, rubber hose, and plastic) form between 50 percent and 75 percent of the ground mass. In some regions, serpentinite fill predominates over industrial debris, usually near the base of the trench. The depth to groundwater varied from 1 to 7 feet, and appeared to coincide with tide changes in San Francisco Bay and local rain events.

4.1.2 IR-02

Over 100 radium-containing point source gamma anomalies were identified in test pits and trenches in IR-02. The distribution of lithologic units within IR-02 predominantly consists of sands in the northern half and gravel in the southern half. A clay unit was encountered around grid location H.00.00 by 16.00.00 between gravel and sand units.

Thirty-four test pits and three trenches were excavated in the IR-02 bay fill area at locations shown on Figure 6. The distribution of trenching sites was optimized to cover all potential radiation anomaly regions and to provide detailed data for the region around grid location H.00.00 by 16.00.00, the area found to contain the most surface radiation anomalies during the SCRS.

Figure B-1 and Overlay A in Appendix B show an interpretation of the maximum subsurface distribution depth, areal extent, and volume of soil that may contain radioluminescent materials in the area surrounding grid location H.00.00 by 16.00.00.

4.1.3 IR-07 and IR-18

Soils were identified during the SCRS in IR-07 and IR-18 that exhibited gamma count rates that were higher than general background at HPA. No radium-containing devices were found at these locations. The potential presence of other radioactive materials from sandblast wastes prompted the excavation of two trenches in these IR sites. IR-07 and IR-18 are composed of three soil types. The hilly area is covered with approximately 1 foot of silty sand overlying 3 feet of silty clays and sandstone. No point source radiation anomalies were encountered during excavations in either IR-07 or IR-18.

The EPA in cooperation with the National Air and Radiation Environmental Laboratory (NAREL) performed petrographic analysis on soil samples collected from both sites. The objective of this analysis was to identify the origin of the source. The results of petrographic analysis have shown that ^{226}Ra in the silty sands is due to naturally occurring radioactive material (EPA 1994 and PRC 1995).

4.2 TRENCH LOG ANALYSIS OBJECTIVES

The trench logs for IR-02 were analyzed for the following objectives: (1) characterize the soil in sufficient detail to define consistent mappable soil units, (2) determine the distribution and type of gamma-emitting sources, (3) establish whether a correlation exists between soil type(s) and the presence of radioactive material, and (4) determine how the distribution of soil types has varied with time.

4.2.1 Distribution of Radioactive Sources in IR-02 Excavations

A total volume of approximately 6,080 cubic feet (ft^3) of soil and debris was excavated from test pits (2,880 ft^3) and from trenches (3,200 ft^3) that contained a total of 111 radioactive point sources. The number of point sources by volume is approximately 1 point source per 54 ft^3 of excavated soil, or one point source in about 2 cubic yards (yd^3) of soil. Trenching indicates that to remove 90 percent of the radioactive material, soil will have to be excavated to a depth of 6.5 feet. As shown on Table 2, approximately 86.5 percent of a total 111 sources were found at depths ranging from 6.5 feet bgs to the surface. The balance of the sources (15) were found distributed from 6.5 feet bgs to bay mud. No point sources or elevated gamma count rates were found after bay mud was encountered. Table 1 identifies excavations that contain radioactive sources. These excavations are clustered in an area approximately 400 feet long and 250 feet wide, as shown in Appendix B on Figure B-1, Overlay B.

4.2.2 Volume of Landfill in IR-02 that Contains Radioactive Sources

The volume of the landfill enclosing these test pits and trenches is estimated to be approximately 148,000 ft^3 or about 5,500 yd^3. The soil volume was calculated using SURFER, a computer-aided drafting program for surface modeling. The SCRS report has already identified the location of over 300 surface point sources buried approximately 1 foot bgs. To remediate these surface sources, assuming none are located below 1 foot, soil would only have to be removed to a depth of 1 foot at each location. Phase II trenching provided additional data that indicated the areas where radioactive sources were located deeper than 1 foot. Using this areal extent and depth data, a theoretical soil volume was modeled using SURFER. A plot of this model is provided in Appendix B, Figure B-1, Overlay A.

The total estimated volume of soil that contains radioactive material was calculated to be 5,500 yd^3. Phase II excavation data identified 1 point source per 2 yd^3 of soil; therefore, the estimated volume would yield about 2,750 radioactive point sources.

4.2.3 Correlation Between Soil Type and Location of Radioactive Material

It does not appear, based upon review of trench logs, that radium-containing materials were placed into an excavated trench and covered with soil. Rather, they were disposed of with other materials without regard to their radioactivity and are not associated with any particular soil type.

A clay unit was found at all depths of fill in IR-02, which indicates that clay was placed in layers, between disposal and fill periods, to extend the landfill into the bay. Although there is an association between the clay type of soil and radioactive anomalies around grid location H.00.00 by 16.00.00, this is not necessarily indicative that they were placed at the same time. This may be due to the disposal trench excavated in the area by Triple A. Gamma-emitting anomalies were detected from 3 inches to 9 feet bgs in a region approximately 300 feet in diameter around grid location H.00.00 by 16.00.00.

There was not any clear association between soil-stratigraphy and the location of gamma-emitting anomalies elsewhere at the site.

4.2.4 Fill Placement Over Time

Analysis of the variations of soil distribution with depth provided little information about fill placement relative to time. Therefore, conclusions cannot be drawn about dates of fill placement.

4.3 DOWNWELL GAMMA LOGGING

Twenty-two groundwater monitoring wells were logged using a gamma detector to locate subsurface gamma-emitting point source anomalies. Only one gamma anomaly was found by this method. A gamma count of 16,326 cpm was recorded in monitoring well IR02MW175A at a depth of 6.5 feet bgs. According to the boring log and construction details for the well, the bentonite well seal extends from 6 to 9 feet bgs; asphalt debris is found from 5 to 6.25 feet bgs, which is underlain by uniformly graded sand from 6.25 to 6.5 feet bgs. At a depth of approximately 6 to 6.5 feet bgs, both the bentonite and asphaltic concrete debris overlap. Certain types of asphaltic concrete aggregate are composed of granitic materials. These granite aggregates contain concentrated amounts of potassium-40 and naturally occurring ^{226}Ra.

It was noted that the gamma count rates at the bentonite seals are higher than the count rates at their adjacent depths in all wells. This activity may be due to a number of factors. Bentonite is composed of various clays, including a type of potassium alumina sulfate called taylorite. Bentonite is hydrated during well construction, absorbing water and expanding into a silica gel. Both water and taylorite contain radioactive potassium, potassium-40, which may explain the elevated gamma counts. An equally valid possibility is that the cement grout above the bentonite seal and sand pack below it are dense enough to prevent background gamma activity from being detected inside the well, giving artificially low values except at the seal.

4.4 AIR PERMEABILITY TESTING OF SOIL

Air permeability testing of soil was done to supplement the radon results obtained during the SCRS. Air permeability results did not assist detection of buried sources using radon flux rate measurements as a guide. The gamma detection method used during the SCRS was limited in that it could not typically detect point sources of radium at a depth greater than 1 foot. It was hypothesized that if radium-containing material was grouped together underground, the localized radon flux rate at the soil surface would be higher than expected background radon flux rates.

It was further hypothesized that *qualitative* inferences could be drawn from radon flux values if the air permeability of the soils could be determined. The hypothesis that incorporated air permeability into phase II used the following assumptions: If a surface location had *low* radon flux rates and underlying soils had *high* air permeability, a *qualitative* inference could be made that suggests that (1) individual radium-containing materials were dispersed widely apart below ground or (2) radium-containing materials were not below ground at that location. If a location had *low* radon flux rates and underlying soils had *low* air permeability, no *qualitative* inference could be made about radium- containing materials below ground.

Because of metal, concrete, and rocks below surface, only a total of five air permeability samples were collected within IR-01 and IR-02. The sampling sites were at locations surrounding and within areas that exhibited elevated gamma activity due to gamma-emitting surface point source anomalies. IR-07 and IR-18 were determined to have no *point source* contamination, and each site appeared to comprise geologically similar types of fill material. Therefore, one air permeability coring was determined to be sufficiently representative of the area.

The measurement of radon flux rates, used as an adjunct to the walkover gamma survey to detect buried radium-containing materials, did not yield conclusive evidence to support or disprove that radium-containing materials were buried below flux rate measurement locations. Results indicated that ^{222}Rn flux rates were not elevated except at locations where gamma-emitting materials were identified at the surface. Radon flux rates were low except at gamma-emitting surface point sources where they had been expected to be elevated.

Although this method of radon flux rate measurement did not detect buried radium-containing materials at HPA, it had been successfully used by TMA/Eberline at the Montclair, New Jersey, Formerly Used Sites Remedial Action Program (FUSRAP) site, to identify the locations of point and diffuse sources of buried radium-containing materials. Surface radon flux measurements have also been evaluated by UNC Geotech for the U.S. Department of Energy as a method to be used where conventional methods using gamma-detection techniques are unable to detect buried radium contamination because of soil shielding (Karp 1988). The results of the report indicate that it is possible to detect buried sources of radium contamination to an approximate maximum depth of 4 feet.

The reason why the radon flux rate measurements failed to provide useful information may be due to the subsurface distribution of radium sources. Results of trenching within IR-02 indicate that the average distribution of point source radium-containing materials is approximately one source per 2 yd^3 of soil, which is based upon the number of sources found in an average soil volume removed from a trench. Therefore, the number and activity of the sources in the landfill may not have provided an adequate release of radon that could be detected at the surface.

4.5 BIOTURBATION

Bioturbation occurs when an organism disturbs or tunnels through soil and mixes it. Earthworms are a prime example of bioturbating organisms. A field observation by a PRC geologist noted that in IR-02, of 100 identified surface point sources of gamma activity, 83 were associated with the burrow spoil piles of ground squirrels. One explanation for this observation is that the point sources were buried then were moved to the surface by the action of burrowing animals. This might explain why fewer point sources were found at 0.5, 2.0, and 3.5 feet bgs. Burrowing animals such as squirrels, jackrabbits, and mice have been observed in the vicinity.

4.6 GROSS ALPHA- AND BETA-EMITTING AIRBORNE PARTICULATE SAMPLING AND OTHER RADIOLOGICAL MONITORING

High volume air sampling results indicated that the airborne concentration of gross alpha- and beta-emitting radioactive particulates during trenching did not significantly increase above established background levels. Radioactivity in the air was less that 1×10^{-15} microcuries per cubic centimeter. This indicates that radioactive dusts were not generated during excavation activities and were not transported off-site.

The results obtained from thermoluminescent dosimetry (TLD), bioassay, and breathing zone and medium-volume air sampling indicate that workers were not exposed to radiation above normal background levels. TLD results indicated that total exposure to workers was less than the laboratory reporting limit of 10 millirem per quarter. The concentration of ^{226}Ra in air was at background and approximately 900 times less than the 9×10^{-13} μCi/ml air concentration limit imposed to assess and control the dose to the general public (10 CFR 20). Urine bioassay was performed for ^{226}Ra, and was below laboratory detection limits of 0.5 picocuries per liter (Zenitech 1993).

5.0 RECOMMENDATIONS

Based on the results of the phase II radiation investigation, the following recommendations are provided:

- No further trenching, downwell gamma logging, radon flux rate measurements, or air permeability testing are recommended. Currently, the data collected during the SCRS and the trenching data provide an adequate characterization of type and subsurface extent of radium-containing materials and the volume of soil that may require remediation within the IR-02 landfill.

- No further radiation investigations are recommended for soils in IR-07 and IR-18 within Parcel B. EPA petrographic analysis has established that all radioactivity in soils at the sites is due to naturally occurring minerals and is not the result of former HPA disposal activities (EPA 1994 and PRC 1995).

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APPENDIX A
LABORATORY ANALYTICAL RESULTS

LABORATORY ANALYTICAL RESULTS

Sample ID/ Trench or Test Pit ID[a]	Radium-226 (pCi/g)	Lead-214 (pCi/g)	Bismuth-214 (pCi/g)
SS-1-IR02/ IR02TP11	1806.60±51.76	1634.50±75.15	1345.40±43.70
SS-2-IR02/ IR02TP12	1539.80±45.63	1386.90±63.79	1226.70±39.85
SS-3-IR02/ IR02TP17	53.64±4.92	40.45±1.98	33.25±1.26
SS-3-IR02[b]/ IR02TP17	46.78±3.74	30.31±1.53	24.62±0.97
SS-4-IR02/ IR02TP21	1999.40±58.30	1680.20±77.23	1356±30.4
SS-5-IR02/ IR02TP15	661.65±20.89	568.71±26.22	466.29±15.23
SS-6-IR02/ IR02TP22	2790.70±75.85	2022.20±92.94	1769.50±18.82
SS-6-IR02[b] IR02TP22	5414.80±142.45	3503.10±160.84	3175.30±40.00
SS-7-IR02/ IR02TP23	20949.00±543.18	15873.00±728.80	12810.00±414.67
SS-8-IR02/ IR02TP25	2372.90±64.90	2191.90±97.48	2044.10±66.19
SS-9-IR02/ IR02TP10	12250.00±334.01	12104.00±555.95	10607.00±343.65
SS-10-IR02/ IR02TR01 - 20'-40'	1705.50±58.19	1634.60±75.38	1456.90±23.53
SS-11-IR02/ IR02TR01 - 60'-80'	10269.00±306.56	10502.00±482.95	10063.00±326.94

Note:

a For specific sample collection locations refer to trench logs in Appendix B, Volume II.

b duplicate measurement

pCi/g picocuries per gram

SUMMARY OF SOIL AIR PERMEABILITY RESULTS

Laboratory Sample ID	Field Sample ID	Native State Air Permeability Vertical Sample API RP40*	
		Effective Permeability (millidarcy)	Air Conductivity (cm/sec)
0155 SP001	IR02-AP02	Disturbed	Sample
0155 SP002	IR02-AP03	15.6	1.0E-06
0155 SP003	IR02-AP04	Disturbed	Sample
0155 SP004	IR02-AP05	432	2.8E-05
0155 SP005	IR07-AP01	0.37	2.4E-08

* Effective confining stress 25 psi at 70° F

APPENDIX C

DOWNWELL GAMMA LOGGING DATA

3/17/93
0445 IRO1MW5ER
Gamma Logging
Casing Pipe Height - 30" Above Surface
30 Sec Counts

-19 ft bgs (casing)	3283 CP/30 sec
-18	3318
-17	3345
-16	3249
-15	3312
-14	3463
-13	3468
-12	3328
-11	3366
-10	3494
- 9	4733
- 8	3581
- 7	3619
- 6	4213
- 5	8266
- 4	2945
- 3	2370
- 2.5	1923

1003 Completed Well [illegible]

[redacted]

1300

IR02MW300A

Casing 2.0 ~~ft~~ above Ground

ft b Casing	Counts/30 sec
20	3
19	3136
18	3578
17	3683
16	3787
15	3739
	3861
14	4304
13	3543
12	3574
11	36.33
10	3742
9	4150
8	3985
7	3419
6	5187
5	4071
4	3776
3	3051
2	
	1679

1430 IR02MW179A

Casing ~~1.5~~ 2.0 ft

ft BCH	Counts/30
-11	2949
-10	2839
-9	3058
-8	3190
7	3373
6	4430
5	5976
4	2524
3	1800
2	1473

[redacted]

200 IR02MW206A 1
Casing at 20ft

FCH	Counts/30sec
20	2829
19	2916
18	2779
17	2524
16	2601
15	2594
14	2357
13	2378
12	2276
11	2255
10	2832
9	6400
8	6612
7	2452
6	2254
5	2468
4	2639
3	2343
2	1562

~~1215~~ 1335 IR02MW175A
Casing at Grade

BGS	Counts/30
-20	2679
-19	2800
18	2702
17	2678
16	2500
15	2285
14	2435
13	2443
12	2215
11	2400
10	4002
9	6030
8	6203
7	7991
6	6392
5	2952
4	2615
3	2467
2	2642
1	2542
0	2279

1 min count at 6.5 bgs
Distinctly elevated count rate at [illegible]

[redacted]

1108 IR01 MW 38A
Casing Ht 1.5 ft

ft BCH	Counts/30 Sec
-20	3009
-19	3046
18	3024
17	3137
16	3131
15	3063
14	3296
13	3312
12	3228
11	3257
10	3406
9	3294
8	3257
7	3744
6	6701
5	3729
4	3229
3	3525
2	2482

1135 IR01 MW44A
Casing 3.0 ft

ft BCH	Counts
-11	3106
-10	3353
-9	3669
8	3738
7	4049
6	4339
5	6692
4	2775
3	1534

[redacted]

130 ~~#~~ IR01 MW 1~~7~~B

2 foot Casing

ft bgs	Counts/30 sec
– 20	2339
– 19	1460
18	1804
17	2218
16	2711
15	2598
14	2592
13	2595
12	4082
11	2444
10	2512
9	2377
8	2872
7	3027
6	3911
5	2834
4	3164
3	2681
2	1486

0950 ~~IR01 MW 1SA~~ IR01 MW

Casing ht ~~3.0 ft~~ 2.0 ft

ft bgs Casing	Counts/30
–20	3957
–19	4082
–18	3955
–17	3794
–16	3777
–15	3871
–14	3880
13	3652
12	3757
11	3602
10	3685
9	3651
8	3721
7	3609
6	4188
5	5900
4	2900
3	3213
2	1735

... Dr... 6/18/96

...202 MW 117A

...ing 15 ft ...s

...below casing top — count/30 sec

11	3533
10	2764
9	2831
8	3073
7	3293
6	3518
5	5819
4	5368
3	2206
2	1670
15	1404

...202 MW 117A

2221 Ratemeter/scaler
SPA-3 Shielded NaI D 97963
Threshold 100keV HV 1300

0900 7/15/93 D. Preston D. McCabe

Down Hole gamma logging
at IR-01MW03A

Casing 1.0 ft

ft b casing top	Count/30
-20 3	3305
-19	2572
-18	3179
-17	2900
-16	2476
-15	2445
-14	2909
-13	3629
-12	4614
-11	4537
-10	6253
-9	3329
-8	2958
-7	3301
-6	3996
-5	4165
-4	3240
-3	1425
-2	1438
-1	1087

6

Time 1015 Date 6/18/93

IR02 MW 101 A2

casing 2.0 ft ags

ft below casing top	count / 30 sec
20	2754
19	2712
18	2327
17	1914
16	2265
15	2070
14	2085
13	2067
12	2454
11	2549
10	2979
9	3131
8	2734
7	2633
6	2720
5	1739
4	2020
3	2626
2	2097

IR02 MW 101 A2

Time 1045 Date 6/18/93

IR02 MW 149 A

casing 3 ft ags

ft below casing top	count / 30 s[ec]
20	3201
19	3123
18	3010
17	3201
16	3173
15	3288
14	3128
13	3219
12	3384
11	3395
10	3352
9	3212
8	3239
7	339[illegible]
6	5456
5	4005
4	2030
3	1356

IR02 MW145A

[redacted]

1710 IR02MW114A

Casing 2.5 ft ags

ft b casing top	cp 30sec
-12	3701
-11	3717
-10	3624
9	3387
8	3284
7	4096
6	6724
5	8815
4	3316
3	2311
2.5	1565

IR02 MW114A3

Time 0950 6/18/93

Site IR02 MW 298A

Casing 2.5 ft ags

Ft below casing top	Count 30sec
-20	3096
-19	3097
-18	2957
-17	2800
-16	2828
-15	2944
-14	3363
13	3621
12	3580
13	3272
10	3316
9	3631
8	2997
7	2747
6	6247
5	7148
4	3413
3	2550
2.5	1587

IR02 MW 299A

2

1030 IR02MW137B
Casing height 2.0 feet

ft bgs (casing)	CP 30sec
20 ~~3035~~ bgs	3035
19	2918
18	3114
17	3107
16	3202
15	2756
14	2990
13	3326
12	3097
11	2919
10	3336
9	3650
8	7251
7	4419
6	3631
5	3846
4	4048
3	3278
2.5	2077

Elevated gamma region

~~1049~~
Completed 1049

1645 - IR02MW141A
Casing height 2.5 feet

ft bgs (casing)	CP 30sec
- 18 ~~3338~~	3338
- 17	2683
- 16	2627
- 15	2895
- 14	3181
- 13	3258
- 12	4053
- 11	4305
- 10	4385
- 9	4180
- 8	4287
- 7	3893
- 6	5691
- 5	6088
- 4	3432
- 3	3364
- 2.5	2155

[redacted]

32 [illegible]
[illegible]

[illegible]

17	[illegible]
16	935
15	855
14	1293
13	1340
12	1472
11	1746
10	1696
9	1774
8	2057
7	2362
6	2956
5	3687
4	5717
3	9464
2	1533

7/2/97

[illegible]
[illegible]
to [illegible] 383

[redacted]

30

440 FROZ MW 183

ft bgs casing	1.5 casing
-20	2739
-19	2837
-18	2889
17	2753
16	2757
15	2792
14	2810
13	2865
12	2828
11	2768
10	3283
9	3661
8	3754
7	3713
6	7282
5	6370
4	2832
3	2203
2	1508

[illegible]

[illegible]

1030 [illegible] MW 183 [illegible] 50

20	
19	
18	
17	
16	
15	[illegible]
14	[illegible]
13	1921
12	[illegible]
11	[illegible]
10	[illegible]
9	[illegible]
8	[illegible]
7	[illegible]
6	[illegible]
5	[illegible]
4	[illegible]
3	[illegible]
2	[illegible]
1	

[illegible]

APPENDIX D

DEPARTMENT OF ENERGY RADIOLOGICAL CONTROL MANUAL GLOSSARY

GLOSSARY

abnormal situation: Unplanned event or condition that adversely affects, potentially affects or indicates degradation in the safety, security, environmental or health protection performance or operation of a facility.

activation: Process of producing a radioactive material by bombardment with neutrons, protons or other nuclear particles.

administrative control level: A numerical dose constraint established at a level below the regulatory limits to administratively control and help reduce individual and collective dose.

airborne radioactivity: Radioactive material in any chemical or physical form that is dissolved, mixed, suspended, or otherwise entrained in air.

airborne radioactivity area: Any area where the concentration of airborne radioactivity, above natural background, exceeds or is likely to exceed 10 percent of the derived air concentration (DAC) values. DAC values are contained in Appendices A and C of 10 CFR 835.

annual limit on intake (ALI): The derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. ALI is the smaller value of intake of a given radionuclide in a year by the reference man (ICRP Publication 23) that would result in a committed effective dose equivalent of 5 rems (0.05 sievert) or a committed dose equivalent of 50 rems (0.5 sievert) to any individual organ or tissue.

As Low As Reasonably Achievable (ALARA): An approach to radiological control to manage and control exposures (individual and collective) to the work force and to the general public at levels as low as is reasonable, taking into account social, technical, economic, practical and public policy considerations. As used in this Manual, ALARA is not a dose limit but a process that has the objective of attaining doses as far below the applicable controlling limits as is reasonably achievable.

ALARA Committee: Multidisciplined forum that reviews and advises management on improving progress toward minimizing radiation exposure and radiological releases.

assessment: Evaluation or appraisal of a process, program or activity to estimate its acceptability.

background radiation: Radiation from:

(1) Naturally occurring radioactive materials which have not been technologically enhanced;

(2) Cosmic sources;

(3) Global fallout as it exists in the environment (such as from the testing of nuclear explosive devices);

(4) Radon and its progeny in concentrations or levels existing in buildings or the environment which have not been elevated as a result of current or prior activities; and

(5) Consumer products containing nominal amounts of radioactive material or producing nominal amounts of radiation.

becquerel (Bq): The International System (SI) unit for activity of radioactive material. One becquerel is that quantity of radioactive material in which one atom is transformed per second or undergoes one disintegration per second.

bioassay: The determination of the kinds, quantities, or concentrations, and, in some cases, locations of radioactive material in the human body, whether by direct measurement or by analysis and evaluation of radioactive materials excreted or removed from the human body.

calibration: The process of adjusting or determining either:

(1) The response or reading of an instrument relative to a standard (e.g., primary, secondary, or tertiary) or to a series of conventionally true values; or

(2) The strength of a radiation source relative to a standard (e.g., primary, secondary, or tertiary) or conventionally true value.

company-issued clothing: Clothing provided by the company, such as work coveralls and shoes. For radiological control purposes, company-issued clothing shall be considered the same as personal clothing.

containment device: Barrier such as a glovebag, glovebox or tent for inhibiting the release of radioactive material from a specific location.

contamination area: Any area where contamination levels are greater than the values specified in Chapter 2, Table 2-2, but less than or equal to 100 times those values.

contamination reduction corridor: A defined pathway though a hazardous waste site contamination reduction zone where decontamination occurs.

continuing training: Training scheduled over a specified time such as over a two-year period for the purpose of maintaining and improving technical knowledge and skills.

continuous air monitor (CAM): Instrument that continuously samples and measures the levels of airborne radioactive materials on a "real-time" basis and has alarm capabilities at preset levels.

contractor senior site executive: The person at a DOE contractor-operated facility or site who has final on-site corporate authority and is often called President, General Manager, Site Manager or Director.

controlled area: Any area to which access is managed in order to protect individuals from exposure to radiation and/or radioactive materials. Individuals who enter only the controlled area without entering radiological areas are not expected to receive a total effective dose equivalent of more than 0.1 rem (0.001 sievert) in a year.

conventionally true value of a quantity: The commonly accepted, best estimate of the true value of a quantity. The conventionally true value and the associated uncertainty will normally be determined by comparison with a national or transfer standard, using a reference instrument that has been calibrated against a national or transfer standard.

counseling: Advice, information exchange and guidance provided to employees on radiologically related topics, such as dose perspectives; potential health effects from radiation exposure; skin contaminations; contaminated wounds; internally deposited radioactivity; pregnancy; and radiation exposure. This advice and guidance is normally provided by knowledgeable, senior professionals from the Radiological Control Organization and other organizations, such as Medical, as appropriate.

critical mass: The smallest mass of fissionable material that will support a self-sustaining chain reaction under specified conditions.

critique: Meetings of personnel involved in or knowledgeable about an event (either a success or an abnormal event) to document a chronological listing of the facts.

declared pregnant worker: A woman who has voluntarily declared to her employer, in writing, her pregnancy for the purpose of being subject to the occupational exposure limits to the embryo/fetus as provided in Article 215.

decontamination: Process of removing radioactive contamination and materials from personnel, equipment or areas.

deposition, new confirmed: A deposition of radioactive material in the body or any organ or tissue of an individual identified during the current reporting period, confirmed through bioassay results to be greater than the site-determined reportable level.

derived air concentration (DAC): For the radionuclides listed in Appendix A of 10 CFR 835, the airborne concentration that equals the ALI divided by the volume of air breathed by an average worker for a working year of 2000 hours (assuming a breathing volume of $2400m^3$). For radionuclides listed in Appendix C of 10 CFR 835, the air immersion DACs were calculated for a continuous, non-shielded exposure via immersion in a semi-infinite atmospheric cloud. The values are based upon the derived airborne concentration found in Table 1 of the U. S. Environmental Protection Agency's Federal Guidance Report No. 11, Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion, published September 1988.

disintegration per minute (dpm): The rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

DOE activity: An activity taken for or by the DOE that has the potential to result in the occupational exposure of an individual to radiation or radioactive material. The activity may be, but is not limited to, design, construction, operation, decontamination or decommissioning. To the extent appropriate, the activity may involve a single DOE facility or operation or a combination of facilities and operations, possibly including an entire site.

DOELAP: Department of Energy Laboratory Accreditation Program for personnel dosimetry under DOE 5480.15.

dose: The amount of energy deposited in body tissue due to radiation exposure. Various technical terms, such as dose equivalent, effective dose equivalent and collective dose, are used to evaluate the amount of radiation an exposed worker receives. These terms are used to describe the differing interactions of radiation with tissue as well as to assist in the management of personnel exposure to radiation.

Some types of radiation, such as neutron and alpha, deposit their energy more densely in affected tissue than gamma radiation and thereby causing more damage to tissue. The term dose equivalent, measured in units of rem, is used to take into account this difference in tissue damage. Therefore 1 rem from gamma radiation causes damage equivalent to 1 rem from alpha radiation. However, it takes one-twentieth as much energy from alpha radiation, as compared with gamma radiation, to produce this 1 rem dose equivalent.

Definitions for dose terms necessary for various exposure calculations and recordkeeping purposes include the following:

absorbed dose (D): Energy absorbed by matter from ionizing radiation per unit mass of irradiated material at the place of interest in that material. The absorbed dose is expressed in units of rad (or gray) (1 rad = 0.01 gray).

collective dose: The sum of the total effective dose equivalent values for all individuals in a specified population. Collective dose is expressed in units of person-rem (or person-sievert).

committed dose equivalent ($H_{T,50}$): The dose equivalent calculated to be received by a tissue or organ over a 50-year period after the intake of a radionuclide into the body. It does not include contributions from radiation sources external to the body. Committed dose equivalent is expressed in units of rem (or sievert).

committed effective dose equivalent ($H_{E,50}$): The sum of the committed dose equivalents to various tissues in the body ($H_{T,50}$), each multiplied by the appropriate weighting factor (w_T) - that is $H_{E,50}=\Sigma w_T H_{T,50}$. Committed effective dose equivalent is expressed in units of rem (or sievert).

cumulative total effective dose equivalent: The sum of the total effective dose equivalents recorded for an individual for each year of employment at a DOE or DOE contractor site or facility, effective January 1, 1989.

deep dose equivalent: The dose equivalent derived from external radiation at a tissue depth of 1 cm in tissue.

dose equivalent (H): The product of the absorbed dose (D) (in rad or gray) in tissue, a quality factor (Q), and all other modifying factors (N). Dose equivalent is expressed in units of rem (or sievert) (1 rem = 0.01 sievert).

effective dose equivalent (H_E): The summation of the products of the dose equivalent received by specified tissues of the body (H_T) and the appropriate weighting factors (W_T) - that is ($H_E = \Sigma W_T H_T$). It includes the dose from radiation sources internal and/or external to the body. The effective dose equivalent is expressed in units of rem (or sievert).

external dose or exposure: That portion of the dose equivalent received from radiation sources outside the body (e.g., "external sources").

internal dose or exposure: That portion of the dose equivalent received from radioactive material taken into the body (e.g., "internal sources").

lens of the eye dose equivalent: The external exposure of the lens of the eye and is taken as the dose equivalent at a tissue depth of 0.3 cm.

quality factor: The principal modifying factor used to calculate the dose equivalent from the absorbed dose; the absorbed dose (expressed in rad or gray) is multiplied by the appropriate quality factor (Q).

shallow dose equivalent: The dose equivalent deriving from external radiation at a depth of 0.007 cm in tissue.

total effective dose equivalent (TEDE): The sum of the effective dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures). Deep dose equivalent to the whole body may be used as effective dose equivalent for external exposures.

weighting factor (w_T): The fraction of the overall health risk, resulting from uniform, whole body irradiation, attributable to specific tissue (T). The dose equivalent to the affected tissue, H_T, is multiplied by the appropriate weighting factor to obtain the effective dose equivalent contribution from that tissue.

whole body: For the purposes of external exposure, head, trunk (including male gonads), arms above and including the elbow, or legs above and including the knee.

dose assessment: Process of determining radiological dose and uncertainty included in the dose estimate, through the use of exposure scenarios, bioassay results, monitoring data, source term information and pathway analysis.

embryo/fetus: Developing human organism from conception until birth. Same as unborn child.

engineering controls: Use of components and systems to reduce airborne radioactivity and the spread of contamination by using piping, containments, ventilation, filtration or shielding.

entrance or access point: Any location through which an individual could gain access to areas controlled for the purposes of radiation protection. This includes entry or exit portals of sufficient size to permit human entry, irrespective of their intended use.

extremity: Hands and arms below the elbow or feet and legs below the knee.

facility: For the purpose of this Manual, a facility includes systems, buildings, utilities, and related activities whose use is directed to a common purpose at a single location. Example include: accelerators, storage areas, test loops, nuclear reactors, radioactive waste disposal systems and burial grounds, testing laboratories, research laboratories, and accommodations for analytical examinations of components. Also includes: pipelines, ponds, impoundments, landfills and the like, and motor vehicles, rolling stock, and aircraft.

filter integrity test: Test performed on High-Efficiency Particulate Air (HEPA) filters to identify any damage to the filter or leakage around the filter.

fixed contamination: Radioactive material that cannot be readily removed from surfaces by nondestructive means, such as casual contact, wiping, brushing or laundering.

flash X-ray unit: Any device that is capable of generating pulsed X-rays.

frisk or frisking: Process of monitoring personnel for contamination. Frisking can be performed with hand-held survey instruments, automated monitoring devices or by a Radiological Control Technician.

general employee: An individual who is either a DOE or DOE contractor employee; an employee of a subcontractor to a DOE contractor; or a visitor who performs work for or in conjunction with DOE or utilizes DOE facilities.

gestation period: The time from conception to birth, approximately 9 months.

gray (Gy): SI unit of absorbed dose. One gray is equal to an absorbed dose of 1 joule per kilogram (100 rads).

high-efficiency particulate air (HEPA) filter: Throwaway extended pleated medium dry-type filter with 1) a rigid casing enclosing the full depth of the pleats, 2) a minimum particle removal efficiency of 99.97 percent for thermally generated monodisperse di-octyl phlalate smoke particles with a diameter of 0.3 micrometer, and 3) a maximum pressure drop of 1.0 inch w.g. when clean and operated at its rated airflow capacity.

high contamination area: Any area where contamination levels are greater than 100 times the values specified in Chapter 2, Table 2-2, of this Manual.

high radiation area: Any area, accessible to individuals, in which radiation levels could result in an individual receiving a deep dose equivalent in excess of 0.1 rem (0.001 Sv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

hot particle: Fuel, activated corrosion product, or other particles of small size that have a high specific activity as a result of nuclear fission or neutron activation.

hot spot: Localized source of radiation or radioactive material normally within facility piping or equipment. The radiation levels of hot spots exceed the general area radiation level by more than a factor of 5 and are greater than 100 mrem (1 mSv) per hour on contact.

infrequent or first-time activities: Radiological work activities or operations that require special management attention and consideration of new or novel radiological controls. The designation of infrequent or first-time activities is specifically applicable to facilities that conduct routine and recurring process operations, and is not applicable to facilities that routinely conduct first-time activities, such as experimental or research facilities.

irradiator: Sealed radioactive material used to irradiate other materials that has the potential to create a radiation level exceeding 500 rad (5 grays) in 1 hour at 1 meter. Although not addressed in this Manual, acceptable radiological controls for irradiator use are specified in Title 10, Code of Federal Regulations, Part 20.1603.

lifetime dose: Total occupational exposure over a worker's lifetime, including external and committed internal dose.

low-level waste: Waste that contains radioactivity and is not classified as high-level waste, transuranic waste, spent nuclear fuel or byproduct material as defined in Section 11e(2) of the Atomic Energy Act, as amended. Test specimens of fissionable material irradiated only for research and development and not for production of power or plutonium may be classified as low-level waste provided the concentration of transuranic activity is less than 100 nCi/g.

mixed waste: Waste containing both radioactive and hazardous components as defined by the Atomic Energy Act and the Resource Conservation and Recovery Act, respectively.

monitoring: Actions intended to detect and quantify radiological conditions.

nuclear criticality: A self-sustaining chain reaction, i.e., the state in which the effective neutron multiplication constant of system of fissionable material equals or exceeds unity.

occupational dose: An individual's dose due to exposure to ionizing radiation (external and internal) as a result of that individual's work assignment. Occupational dose does not include planned special exposures, exposure received as a medical patient, background radiation, or voluntary participation in medical research programs.

personnel dosimetry: Devices designed to be worn by a single person for the assessment of dose equivalent such as film badges, thermoluminescent dosimeters (TLDs), and pocket ionization chambers.

personnel monitoring: Systematic and periodic estimate of radiation dose received by personnel during working hours. Also, the monitoring of personnel, their excretions, skin or any part of their clothing to determine the amount of radioactivity present.

personal protective equipment: Equipment such as respirators, face shields and safety glasses used to protect workers from excessive exposure to radioactive or hazardous materials.

planned special exposure: Preplanned, infrequent exposure to radiation, separate from and in addition to the annual dose limits.

prefilter: Filter that provides first stage air filtration to remove larger particulates and prolong the efficient use of a HEPA filter.

prenatal radiation exposure: The exposure of an embryo/fetus to radiation.

primary dosimeter: A dosimeter worn on the body used to obtain the formal record of whole body radiation dose.

protective clothing: Clothing provided to personnel to minimize the potential for skin, personal and company issued clothing contamination. Also referred to as "anticontamination clothing," "anti-Cs" and "PCs."

public: Any individual or group of individuals who is not occupationally exposed to radiation or radioactive material. An individual is not a "member of the public" during any period in which the individual receives an occupational dose.

qualification standard: The explicit performance requirements for minimum proficiency in technical, academic, and site-specific knowledge and practical skills used in determining satisfactory completion of training programs. The qualification standard is used to qualify radiological control technicians (RCTs) at DOE facilities.

rad: Unit of absorbed dose. One rad is equal to an absorbed dose of 100 ergs per gram or 0.01 joules per kilogram (0.01 gray).

radiation or ionizing radiation: Alpha particles, beta particles, gamma rays, X-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions. Radiation as used in this manual does not include non-ionizing radiation, such as radio-, or micro-waves, or visible, infrared, or ultraviolet light.

radiation area: Any area, accessible to individuals, in which radiation levels could result in an individual receiving a deep dose equivalent in excess of 0.005 rem (0.05 mSv) in one hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

radioactive material: For the purposes of this Manual, radioactive material includes any material, equipment or system component determined to be contaminated or suspected of being contaminated. Radioactive material also includes activated material, sealed and unsealed sources, and material that emits radiation.

radioactive material area: An area or structure where radioactive material is used, handled or stored.

radioactive waste: Solid, liquid or gaseous material that contains radionuclides regulated under the Atomic Energy Act, as amended, and is of negligible economic value considering the cost of recovery.

radioactivity: A natural and spontaneous process by which the unstable atoms of an element emit or radiate excess energy from their nuclei and, thus, change (or decay) to atoms of a different element or to a lower energy state of the same element.

radiography: Examination of the structure of materials by nondestructive methods, using a radioactive source or a radiation generating device.

radiological area: Any area within a controlled area (but not including the controlled area) which must be posted as required by Chapter 2, Part 3 of this Manual.

radiological buffer area (RBA): A intermediate area established to prevent the spread of radioactive contamination and to protect personnel from radiation exposure.

radiological control hold point: Cautionary step in a technical work document requiring the radiological control organization to perform some action or verification. The radiological control hold point requirements should be satisfactorily completed before the work is continued.

radiological label: Label on an item which indicates the presence of radiation or radioactive materials.

radiological posting: Sign, marking, or label that indicates the presence or potential presence of radiation or radioactive materials.

radiological work: Any work that requires the handling of radioactive material or which requires access to Radiation Areas, High Radiation Areas, Contamination Areas, High Contamination Areas or Airborne Radioactivity Areas.

radiological work permit (RWP): Permit that identifies radiological conditions, establishes worker protection and monitoring requirements, and contains specific approvals for radiological work activities. The Radiological Work Permit serves as an administrative process for planning and controlling radiological work and informing the worker of the radiological conditions.

radiological workers: General employees who are required to complete Radiological Worker I or II training because their job assignment requires work on, with, or in the proximity of radiation producing machines or radioactive materials. A radiological worker has the potential of being exposed to more than 0.1 rem (1 mSv) per year, which is the sum of the dose equivalent from external irradiation and the committed effective dose equivalent from internal irradiation. A "radiological worker" may also be referred to as a "radiation worker" or a "radworker." Individuals who complete either Radiological Worker I or Radiological Worker II Training are considered radiological workers.

refresher training: Training scheduled on the alternate year when full retraining is not completed for Radiological Worker I and Radiological Worker II personnel.

release to uncontrolled areas: Release of material from administrative control after confirming that the residual radioactive material meets the guidelines in DOE 5400.5.

rem: Unit of dose equivalent. Dose equivalent in rem is numerically equal to the absorbed dose in rad multiplied by a quality factor, distribution factor and any other necessary modifying factor (1 rem = 0.01 sievert).

removable contamination: Radioactive material that can be removed from surfaces by nondestructive means, such as casual contact, wiping, brushing or washing.

representative sample: A sample that closely approximates both the concentration of activity and the physical and chemical properties of material (e.g., particle size and solubility in case of air sampling of the aerosol to which workers may be exposed).

respiratory protective equipment: Equipment used to protect personnel from inhalation of radioactive or hazardous materials.

sievert (Sv): SI unit of any of the quantities expressed as dose equivalent. The dose equivalent in sieverts is equal to the absorbed dose in grays multiplied by the quality factor (1 Sv = 100 rems).

site: An area managed by DOE where access can be limited for any reason. The site boundary encompasses Controlled Areas.

sealed radioactive source: Radioactive material that is contained in a sealed capsule, sealed between layer(s) of nonradioactive material, or firmly fixed to a nonradioactive surface by electroplating or other means. The confining barrier prevents dispersion of the radioactive material under normal and most accidental conditions related to use of the source.

standard radiation symbols: Symbols designed and proportioned as illustrated in accordance with ANSI N2.1 for radiation symbols and ANSI N12.1 for fissile material.

step-off pad: Transition area between contaminated and non-contaminated areas that is used to allow exit of personnel and removal of equipment.

sticky pad: Step-off pad provided with a tacky surface to reduce the potential for inadvertently tracking contamination out of a contaminated area.

survey: An evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal, or presence of radioactive material or other sources of radiation. When appropriate, such an evaluation includes a physical survey of the location of radioactive material and measurements or calculations of levels of radiation, or concentrations or quantities of radioactive material present.

technical work document: A term used to generically identify formally approved documents that direct work, such as procedures, work packages, or job or research plans.

thermoluminescent dosimeter (TLD): Radiation monitoring device used to record the radiological exposure of personnel or areas to certain types of radiation.

transuranic waste: Without regard to source or form, waste that is contaminated with alpha-emitting transuranic radionuclides having half-lives greater than 20 years and concentrations greater than 100 nCi/g at the time of assay.

unusual occurrence: Nonemergency occurrence that has significant impact or potential for impact on safety, environment, health, security, or operations. Examples of the types of occurrences that are to be categorized as unusual occurrences are contained in DOE 5000.3A.

very high radiation area: Any area, accessible to individuals, in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads (5 grays) in one hour at 1 meter from a radiation source or from any surface that the radiation penetrates.

visitor: Person requesting access to Controlled Areas who has not been trained to the level required to permit unescorted access.

whole body dose: The sum of the annual deep dose equivalent for external exposures and the committed effective dose equivalent for internal exposures.

year: The period of time beginning on or near January 1 used to determine compliance with the provisions of this Manual. The starting date of the year used to determine compliance may be changed provided that the change is made at the beginning of the year and that no day is omitted or duplicated in consecutive years.